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In the Supreme Court of the United States

OCTOBER TERM, 1979

SIDNEY A. DIAMOND, COMMISSIONER OF PATENTS AND TRADEMARKS, PETITIONER

v.

JAMES R. DIEHR, II, AND THEODORE A. LUTTON

PETITION FOR A WRIT OF CERTIORARI TO THE UNITED STATES COURT OF CUSTOMS AND PATENT APPEALS

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The Solicitor General, on behalf of the Commissioner of Patents and Trademarks, petitions for a writ of certiorari to review the judgment of the United States Court of Customs and Patent Appeals in this case.

OPINIONS BELOW

The opinion of the Court of Customs and Patent Appeals (App. A, *infra*) is reported at 602 F.2d 982. The opinion of the Patent and Trademark Office Board of Appeals (App. C, *infra*) and the opinions of the patent examiner (App. D, *infra*) are not reported.

JURISDICTION

The judgment of the Court of Customs and Patent Appeals was entered on August 9, 1979, and a timely petition for rehearing was denied on October 18, 1979 (App. B, *infra*). The jurisdiction of this Court is invoked under 28 U.S.C. 1256. *Gottschalk* v. *Benson*, 409 U.S. 63 (1972); *Dann* v. *Johnston*, 425 U.S. 219 (1976).

QUESTION PRESENTED

Whether a computer program that regulates the curing time of rubber products in a mold is patentable subject matter under 35 U.S.C. 101.

STATUTE INVOLVED

35 U.S.C. 101 provides:

> Whoever invents or discovers any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof, may obtain a patent therefor, subject to the conditions and requirements of this title.

STATEMENT

On August 6, 1975, James R. Diehr, II, and Theodore A. Lutton applied for a patent on a process using a computer for regulating the curing time of rubber products in a mold press (App. E, *infra*, 38a, 41a).[1]

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[1] The invention is assigned to Federal-Mogul Corporation, Detroit, Michigan. Brief for Appellants at 1, *In re Diehr*, 602 F.2d 982 (C.C.P.A. 1979).

Rubber products produced from a mold press are cured in the press for a specified time (App. E, *infra*, 39a-40a). The time needed to obtain a good cure depends in part on the temperature inside the press, which is regulated by a thermostat (*ibid.*).[2] It is possible, using well-known time, temperature, and cure relationships, to calculate when to open the press and remove the cured product (App. E, *infra*, 39a, 49a). Nonetheless, uncontrolled variables present in the actual curing process make it difficult to arrive at an exact temperature for purposes of doing the necessary computations. The time the press is open while it is being loaded, for example, affects the temperature inside the press when it is first closed and thus influences the time it takes to heat the press to the desired temperature (App. E, *infra*, 39a). For this reason, industry practice is to calculate the cure time as the shortest time in which all parts of the product definitely will be cured, assuming a "reasonable amount of mold-opening time" during loading and unloading (App. E, *infra*, 40a). The disadvantages of this practice are that erring on the side of caution will usually lead to overcuring the rubber, while keeping the mold open for more than a "reasonable" time will often result in undercuring (*ibid.*).

Diehr's claimed invention employs a digital computer to overcome these drawbacks. Measurement of

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[2] The geometric configuration of the press and the viscosity of the rubber when it enters the press are also important factors in computing the cure time (App. E, *infra*, 46a-47a, 48a, 49a).

the temperature in the closed, heated press is made "continuously," for example, every ten seconds (App. E, *infra*, 41a). These measurements are automatically fed into the computer (App. E, *infra*, 41a, 45a). For each new measurement, the computer recalculates the cure time in accordance with a well-known mathematical formula, the Arrhenius equation (App. E, *infra*, 41a-42a, 46a). When the recalculated cure time equals the actual time that has elapsed since the press was closed, the computer signals a device to open the press (App. E, *infra*, 42a, 45a). Diehr's claims describe both the method for operating the press using the computer and, more generally, the method for manufacturing molded articles, including the steps of putting rubber into the press, closing and heating the press, and opening the press to remove the molded product (App. E, *infra*, 44a-62a).

The patent examiner rejected the invention as drawn to nonstatutory subject matter under 35 U.S.C. 101 (App. D, *infra*, 26a-37a). He concluded that those steps in Diehr's claims that are "carried out by the computer under control of a stored program" are nonstatutory under *Gottschalk* v. *Benson*, 409 U.S. 63 (1972) (App. D, *infra*, 28a, 33a-34a). The remaining steps—which relate generally to the method of manufacturing precision molded articles, such as the opening, closing, and heating of the mold —the examiner found to be "conventional" (App. D, *infra*, 28a, 33a).

The Patent and Trademark Office Board of Appeals (Board) unanimously affirmed the rejection. The

Board found that Diehr's specifications, while not listing a computer program as such, in fact contained a "sufficient" description from which a "person of ordinary skill in the art" could write a computer program (App. C, *infra*, 21a-22a). Analyzing the claims, the Board found much that was either within the prior art, such as the constant measurement of the mold temperature, or that involved post-solution activity, such as the automatic opening of the press. The "calculation" recited in the claims, observed the Board, shows that Diehr's system employs an algorithm (App. C, *infra*, 22a-24a). The Board summarized: "[T]he only difference between the conventional methods of operating a molding press and that claimed * * * rests in those steps * * * which relate to the calculation incident to the solution of the mathematical problem or formula" (App. C, *infra*, 24a). The Board concluded that this calculation, Diehr's "contribution," was "a computer program of the character" that is nonstatuotry under *Gottschalk* v. *Benson*, *supra*, and *Parker* v. *Flook*, 437 U.S. 584 (1978) (App. C, *infra*, 24a).

The Court of Customs and Patent Appeals (CCPA) reversed. It agreed with the Board that Diehr had "disclosed a computer program" (App. A, *infra*, 5a n.3), but it stated that this "does nothing to aid in the determination of compliance with § 101" (App. A, *infra*, 8a) and is not "of any significance" (App. A, *infra*, 14a). It held that this Court's analysis detailed in *Flook* was merely "a convenient vehicle" for finding the "method[] of calculation" there to be nonstatutory, and did not establish "a

general test in determining compliance with § 101" (App. A, *infra*, 13a-14a n.6). Thus it refused to identify and set aside, as had the Board, those steps in the claim that were old in the art (App. A, *infra*, 13a-14a, 16a-17a), stressing that, "[c]onsiderations of novelty and obviousness have no bearing on compliance with § 101" (App. A, *infra*, 13a). The CCPA instead considered the "claims, *as a whole*" (App. A, *infra*, 13a-14a, 15a) (emphasis in original) and found that they recite "a process or method for molding rubber articles" (App. A, *infra*, 15a), at whose "heart" is a molding press, not an equation or method of calculation (App. A, *infra*, 16a). Since this "process" constituted "an improvement over prior processes" (App. A, *infra*, 15a) themselves patentable subject matter, the court below concluded that Diehr's "process" was likewise patentable (App. A, *infra*, 15a-18a).

REASONS FOR GRANTING THE PETITION

For the second time in as many months the Court of Customs and Patent Appeals has refused to apply the analysis of patent claims required under *Parker* v. *Flook*, 437 U.S. 584 (1978). This decision and that in *In re Bradley*, 600 F.2d 807 (C.C.P.A. 1979) bring into serious question that court's willingness to abide by this Court's decisions. See also *In re Bergy*, 596 F.2d 952, 966 (C.C.P.A. 1979), cert. granted, No. 79-136 (Oct. 29, 1979); and a very recent third instance, *In re Sherwood*, No. 79-579 (C.C.P.A. Jan. 10, 1980). Since the CCPA's failure

to follow *Flook* is an error also raised in our petition for certiorari in *Diamond* v. *Bradley*, No. 79-855, we suggest that this Court consider this case with *Bradley*.[3]

The facts of this case are remarkably similar to those of *Parker* v. *Flook*, *supra*. The patent application in *Flook* described a three-step method for a computer to update alarm limits in catalytic conversion processes. The steps were: (1) measurement of the present value of the process variable, for example, temperature; (2) use of a mathematical formula in a computer program to calculate an updated alarm-limit value; and (3) actual adjustment of the alarm limit to the updated value. 437 U.S. at 585-586. The present application also describes a three-step method for computer operation of an industrial process—this time in the curing of rubber. The steps are: (1) measurement of the present value of the process variable, temperature; (2) use of a mathematical formula in a computer program to calculate an updated cure time;[4] and (3) direction of the mold presses to open in accordance with the updated cure time.

Perceiving the similarity of the two cases, the Board of Appeals held that the analysis of the claim which this Court performed in *Flook* was also re-

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[3] We have sent respondents a copy of our petition in *Bradley;* we are sending respondents in *Bradley* a copy of this petition.

[4] The underlying mathematical formula here, the Arrhenius equation, is old in the art, while the underlying formula in *Flook* was novel.

quired here. It thus identified and put aside the computer implemented algorithm in the claims and considered whether what remains is old in the art. Compare 437 U.S. at 594 with App. C, *infra*, 22a-25a. It found that everything in Diehr's claim except that algorithm was "conventional" (App. C, *infra*, 24a). It concluded that Diehr was attempting to patent an unpatentable algorithm embodied in a computer program (App. C, *infra*, 23a, 24a).

The Court of Customs and Patent Appeals acknowledged that the claim encompassed a mathematical algorithm (App. A, *infra*, 14a). Moreover, it did not reverse the Board's factual finding that everything in Diehr's claim except the use of the computer to calculate the cure time was old in the art (App. A, *infra*, 13a).[5] It held, however, that this finding was irrelevant (*ibid.*). The court refused to follow the *Flook* analysis, asserting that this Court never "meant to establish that analysis as a general test" (App. A, *infra*, 14a n.6). Viewing the claims "as a whole", it perceived "a process involving the manipulation of apparatus resulting in the chemical and physical change of starting material"

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[5] Diehr contested the Board's finding that the step of continuously measuring the temperature in the press was not novel (App. C, *infra*, 22a; App. A, *infra*, 13a). The court, while expressing an inclination to agree with Diehr, did not decide the question because it held it irrelevant (App. A, *infra*, 13a, 14a). The Board, however, is correct on this factual issue. The examiner cited (App. D, *infra*, 30a) two patents, Gould and Davis, which anticipate Diehr's idea. See Apps. F and G, *infra*, 64a, 67a-68a, 70a-72a, 73a, 75a-76a, 78a, 80.

whose calculation, unlike Flook's, was "intimately entwined with the rubber molding process recited" (App. A, *infra*, 16a, 17a).

The CCPA's decision emasculates *Flook*. The court simply asserted that the *Flook* analysis can be ignored because it was not meant to have general applicability (App. A, *infra*, 13a-14a n.6). But nothing in *Flook* remotely suggests that this Court intended to limit its reasoning to that one case and its particular algorithm and program. *Flook* provides the method of analysis for the generality of cases involving algorithms or computer programs; while the CCPA may not like the decision (see *In re Bergy*, *supra*, 596 F.2d at 966), it can scarcely avoid it by asserting that this Court's analysis in *Flook* should not be applied in other, similar cases. See also our petition in *Diamond* v. *Bradley*, No. 79-855, at 8-10, 12-13. Indeed, the CCPA's approach would make meaningless this Court's explicit rationale in *Flook* that Congress has yet to decide the "[d]ifficult questions of policy concerning the kinds of [computer] programs that may be appropriate for patent protection and the form and duration of such protection." 437 U.S. at 595.

Had the CCPA followed *Flook*, it would have focused on a critical fact that requires rejection of Diehr's application: everything described in Diehr's claim is old except for the use of a computer to recalculate cure time. His claim amounts at most to providing "a new and presumably better method for calculating" cure times. Compare *Parker* v. *Flook*,

supra, 437 U.S. at 594. But this mathematical algorithm, conventionally embodied in a computer program, is no more patentable than the formula was in *Flook*.[6] It is simply not statutory subject matter. *Parker* v. *Flook*, *supra*, 437 U.S. at 594-595.

CONCLUSION

The petition for a writ of certiorari should be granted.

Respectfully submitted.

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[6] Thus the CCPA's characterization of the claim as "a process involving the manipulation of apparatus" with the algorithm "intimately entwined" in that process (App. A, *infra*, 17a) is without legal significance. The same description could be applied to Flook's claim.

APPENDIX A

UNITED STATES COURT OF CUSTOMS AND PATENT APPEALS

Appeal No. 79-527

IN THE MATTER OF THE APPLICATION OF
JAMES R. DIEHR, II, and THEODORE A. LUTTON

Serial No. 602,463

Decided: August 9, 1979

Before MARKEY, Chief Judge, RICH, BALDWIN, and MILLER, Associate Judges, and COWEN,* Senior Judge.

RICH, Judge.

This appeal is from the decision of the Patent and Trademark Office (PTO) Board of Appeals (board) affirming the rejection of claims 1-11, all claims in appellants' application serial No. 602,463, filed August 6, 1975, entitled "Direct Digital Control of Rubber Molding Presses." [1] The claims have been rejected

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* The Honorable Wilson Cowen, United States Court of Claims, sitting by designation.

[1] This application is a continuation of application serial No. 472,595, filed May 23, 1974, now abandoned, which is a continuation-in-part of application serial No. 401,127, filed September 26, 1973, now abandoned.

under 35 USC 101 as being drawn to nonstatutory subject matter. We reverse.

The Invention

Appellants claim a method for operating molding presses used in the manufacture of rubber articles. More specifically, appellants' method produces molded articles which are properly cured, in that their method insures that the articles remain in the press for a period of time sufficient to insure that they are not overprocessed or underprocessed.

According to appellants' specification, achieving a perfect cure depends upon several factors, including the thickness of the article to be molded, the temperature of the molding press, and the amount of time that the article is allowed to remain in the press. These factors are related by the Arrhenius equation, [2] which appellants acknowledge has always been used to calculate the cure time in rubber molding processes.

From a reading of appellants' specification and their brief before this court, it appears that they characterize their contribution to the art as residing

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[2] The Arrhenius equation is expressed as follows:

$$\ln v = C Z + x$$

wherein ln v is the natural logarithm of v, the total required cure time; C is the activation constant, a unique figure for each batch of each compound being molded, determined in accordance with rheometer measurements of each batch; Z is the temperature in the mold; and x is a constant dependent on the geometry of the particular mold in the press.

A rheometer is an instrument to measure flow of viscous substances.

in the step of repeatedly or constantly measuring the actual temperature in the mold. These temperature measurements are then used to calculate the cure time by repeatedly using the Arrhenius equation to arrive at the actual cure time, rather than by the conventionl method which uses a single calculation using that equation based upon the temperature nominally set by a thermostat which controls the heater in the molding press. The conventional method is inherently inaccurate because the temperature value used in the equation is rarely, if ever, the true temperature in the mold environment.

Claim 1 is representative and reads:

> 1. A method of operating a rubber-molding press for precision molded compounds with the aid of a digital computer, comprising:
>
> providing said computer with a data base for said press including at least,
>
> natural logarithm conversion data (ln),
>
> the activation energy constant (C) unique to each batch of said compound being molded, and
>
> a constant (x) dependent upon the geometry of the particular mold of the press,
>
> initiating an interval timer in said computer upon the closure of the press for monitoring the elapsed time of said closure,
>
> constantly determining the temperature (Z) of the mold at a location closely adjacent to the mold cavity in the press during molding,

constantly providing the computer with the temperature (Z),

repetitively calculating in the computer, at frequent intervals during each cure, the Arrhenius equation for reaction time during the cure, which is

$$\ln v = C Z + x$$

where v is the total required cure time,

repetitively comparing in the computer at said frequent intervals during the cure each said calculation of the total required cure time calculated with the Arrhenius equation and said elapsed time, and

opening the press automatically when a said comparison indicates equivalence.

The other claims are similar. Claim 11 does not recite the use of a computer to do the calculating, but, as we shall explain, we find this fact to be of no moment.

The Rejection

The examiner rejected the claims because he believed that *the only non-conventional claim steps* "define a computer program for taking repeated temperature measurements from the mold and calculating cure time in response to said measurement data." On this basis, he decided that appellants were *claiming* a computer program, "subject matter [to] which the Supreme Court has declined to extend patent protection absent a considered action by Congress."

The board agreed with the examiner. It dismissed appellants' argument that no computer program was

disclosed in the specification, citing an admission to the contrary made by appellants during prosecution.[3] The board was aware of the then newly announced Supreme Court decision in *Parker* v. *Flook*, 437 U.S. 584, 198 USPQ 193 (1978) (hereinafter *Flook*), and made use of it in support of its decision to affirm the rejection.

The board, in its examination of claim 1, perceived the only "non-programming" step to be "constantly determining the temperature (Z) of the mold," and stated that according to appellants' specification, in "Background of the Invention," it was old in the art. The board analyzed the other steps recited in claim

---

[3] Appellants have consistently argued that they have not disclosed a computer program in their specification, but in a preliminary amendment, filed August 6, 1975, with their application, they stated:

> The original affidavit by applicants under Rule 132 disclosed that the flow sheet [Figs. 3A and 3B of the specification] is itself basically a program and that the only difference between the flow sheet as a program and the form taken by the program when it gets into the computer is translation into a suitable computer language * * *.

An affidavit of the applicants, dated July 18, 1975, states:

> THAT the program shown in the flow sheets, Figs. 3A and Fig. 3B, is actually a "program" so far as the programmer is concerned and that to apply the "program" * * * to a computer merely involves translation of the symbolic flow sheet into [a suitable computer language].

Thus, by their own admission, it is clear that appellants have disclosed a computer program. However, this fact, by itself, has no significance in the § 101 inquiry, as we shall explain, infra.

1 as being directed to gathering data for use in the recited formula or as "post solution activity," which, according to *Flook*, would not render the claims statutory. The board concluded that appellants' system involves an algorithm solving a mathematical problem in the sense involved in *Flook*.

After similarly analyzing the remainder of the appealed claims, the board concluded as follows:

> It is our view that the only difference between the conventional methods of operating a molding press and that claimed in appellants' application rests in those steps of the claims which relate to the calculation incident to the solution of the mathematical problem or formula used to control the mold heater and the automatic opening of the press.
>
> We think that *appellants' contribution, regardless of claim format*, is a computer program of the character which the USSC has indicated, in both Flook and Benson,[4] is outside the bounds of 35 USC 101. [Emphasis ours.]

Appellants' Arguments

Appellants argue that they have *claimed a process* which is basically chemical and physical in nature, not a computer program or the type of mathematical algorithm involved in *Flook*. They do, however, as they must, acknowledge that calculations according to a recited formula are explicitly *involved in* the claimed process.

---

[4] *Gottschalk* v. *Benson*, 409 U.S. 63, 175 USPQ 673 (1972).

They strenuously take issue with the factual conclusion made by both the examiner and the board that their step of continuously measuring the temperature in the mold cavity is old in the art. They attribute this error to a misreading of their specification and assert that they are the first to employ this step in the molding process.

Appellants also say that the PTO has erred by dissecting their claims into what the PTO considers to be novel and nonnovel elements in order to wrongfully conclude that they are claiming a computer program. They assert that the Supreme Court has never placed a blanket prohibition on the patenting of computer programs and, consequently, that the labeling of an invention as a computer program is not a proper method by which to reject a claim under § 101.

Finally, they argue that there is no prohibition on the patenting of all inventions which involve the use of a computer and that their invention, while it does involve the use of a mathematical formula, does not claim the mathematical formula in a nonstatutory manner. They say that their claims, as entireties, do not define methods of solving a mathematical problem and are statutory under this court's test applied in *In re Johnson*, 589 F.2d 1070, 200 USPQ 199 (CCPA 1978).

OPINION

A claim drawn to a process or method does not depend for its validity under 35 USC 101 on whether a computer is involved. If the claim is drawn to sub-

ject matter, *which is otherwise statutory*, it does not become nonstatutory merely because a computer is involved in its execution. Thus, the fact that it may be said that an invention is drawn to a computer program or involves a computer is an observation which does nothing to aid in the determination of compliance with § 101. *In re Gelnovatch*, 595 F.2d 32, 36-37, 201 USPQ 136, 141 (CCPA 1979); *In re Johnson*, 589 F.2d 1070, 1081, 200 USPQ 199, 210-11 (CCPA 1978); *In re Chatfield*, 545 F.2d 152, 155, 191 USPQ 730, 733 (CCPA 1976). Therefore, any rejection which is based solely on the determination that a computer or computer program is involved is insupportable because it is overly broad and must be reversed as being without basis in the law.

The Supreme Court, in the two instances in which it has addressed itself to the § 101 issue in cases where computer-related inventions are involved, has not said anything to the contrary. Our view is not in any way inconsistent with these precedents.

In *Gottschalk* v. *Benson*, supra n. 4 (hereinafter *Benson*), the Court addressed a claimed method for converting binary coded decimal (BCD) numbers to equivalent pure binary numbers. The Court observed that the claims were "not limited to any particular art or technology, to any particular apparatus or machinery, or to any particular end use. They purported to cover any use of the claimed method in a general-purpose digital computer of any type." 409 U.S. at 64, 175 USPQ at 674. The court determined that the claimed method was a mathematical algo-

rithm, i.e., a "procedure for solving a given type of mathematical problem," and further, that "The mathematical procedures can be carried out in existing computers long in use, no new machinery being necessary. And, as noted, they can also be performed without a computer." *Id.* at 65, 67, 175 USPQ at 674, 675.

The Court reviewed long-standing precedent to the effect that while an abstract principle or idea, or a scientific truth, or its equivalent mathematical expression is nonstatutory, an invention created from the *application* of such a truth or useful *structure* created therefrom is statutory.

The Court then proceeded to hold Benson's invention to be nonstatutory with the following statements (*Id.* at 71-72, 175 USPQ at 676, emphasis ours):

> We do not hold that no process patent could ever qualify if it did not meet the requirements of our prior precedents. *It is said that the decision precludes a patent for any program servicing a computer. We do not so hold.* It is said that we have before us a program for a digital computer but extend our holding to programs for analog computers. We have, however, made clear from the start that we deal with a program only for digital computers. It is said we freeze *process patents* to old technologies, leaving no room for the revelations of the new, onrushing technology. *Such is not our purpose.* What we come down to in a nutshell is the following.
>
> *It is conceded that one may not patent an idea. But in practical effect that would be the result*

if the formula for converting BCD numerals to pure binary numerals were patented in this case. The mathematical formula involved here has no substantial practical application except in connection with a digital computer, which means that if the judgment below is affirmed, the patent would wholly pre-empt the mathematical formula and in practical effect would be a patent on the algorithm itself.

From the Court's holding itself, as well as from its discussion of the applicable legal principles, it is clear that the claims were held to be fatally deficient under § 101, *not because a computer program was being claimed,* but because a *mathematical formula* or algorithm per se was being claimed. Important to the Court's reasoning was the fact that the formula involved dealt with the binary radix, or base two number system. The only practical and significant application of the binary system in the real world is in connection with digital computers, which operate in the binary system—a system easily represented electrically by the "on" and "off" or conducting and nonconducting states of the circuit elements comprising the computer. Seen in this light, it is apparent that the claim would, in effect, dominate all practical and significant uses of the formula. Thus, the Court viewed the claim as directed to the scientific truth itself, rather than to an *application* of, or *structure* created with the aid of, the scientific truth. This belies any notion that the claims were held to be nonstatutory because drawn to a computer program per se.

Parker v. *Flook*, supra, presented the Supreme Court with a similar situation. The claims were drawn to a method for updating an alarm limit used in petroleum refining processes. The Court determined that the claims were essentially directed to the use of a new *mathematical formula* in the conventional process of updating alarm limits. According to the majority, "Respondent's application [sic, claimed invention] simply provides a new and presumably better method for calculating alarm limit values." 437 U.S. at 594-95, 198 USPQ at 199 (emphasis ours). As in *Benson*, the Court in *Flook* was simply saying that the claims were an attempt to patent *the scientific truth itself*, rather than an application of the truth or a structure created by its use." "[I]f a claim is directed essentially to a method of calculating, using a mathematical formula, even if the solution is for a specific purpose, the claimed method is nonstatutory." 437 U.S. at 595, 198 USPQ at 199, *quoting In re Richman*, 563 F.2d 1026, 1030, 195 USPQ 340, 343 (CCPA 1977).

The Court's holding in *Flook* was "very simply" stated: "[O]ur holding today is that a claim for an improved *method of calculation*, even when tied to a specific end use, is unpatentable subject matter under § 101." *Id.* n. 18. (Emphasis ours.) As in *Benson*, this holding has nothing to do with computers or computer programs per se.

This, as we perceive it, is the direction which has been given us by the Supreme Court. Until the Court directs us otherwise, we continue to disagree with the

notion that a claim may be rejected as nonstatutory merely because it *involves* a computer program or is computer-related. As far as we are concerned, claims may be rejected under § 101 because they attempt to embrace *only* a mathematical formula, mathematical algorithm, or method of calculation, but not merely because they define inventions having something to do with a computer.

In view of the foregoing, to the extent that the examiner's position is based upon the mere alleged presence of a computer program in appellants' claims, it is without basis in the law and cannot be sustained. The Board, however, in addition to stating the inadequate reason that a computer program is involved, analyzed the claims to determine what steps in the process were old or conventional and apparently ignored such steps, confining its consideration to the nature of what it deemed to be "appellants' contribution." It then found that contribution to be a "computer program" relating to a calculation incident to the solution of a mathematical problem or formula used to control the opening of the press, and, for that reason, held the claims to be drawn to nonstatutory subject matter under *Flook* and *Benson*. We wish to make clear that this analysis is the only basis upon which we are reviewing the rejection, and that, but for this reasoning, we would be constrained to summarily reverse or remand this case to the board for an adequate analysis. *See In re Phillips*, 593 F.2d 1021, 201 USPQ 257 (CCPA 1979).

Appellants and the PTO have locked horns over whether the step of continually measuring the temperature in the mold cavity is old in the art. While we are inclined to agree with appellants that the record is devoid of any evidence that *this step* was ever performed by persons other than appellants,[5] we fail to see what relevance this issue has to the § 101 inquiry. Considerations of novelty and obviousness have no bearing on compliance with § 101. *In re Bergy*, 596 F.2d 952, 960-61, 962-63, 201 USPQ 352, 361, 362 (CCPA 1979); *Nickola* v. *Peterson*, 580 F.2d 898, 906-907, 198 USPQ 385, 395-96 (6th Cir. 1978). Thus, the fact that certain limitations in a claim may be novel and certain others may be old is irrelevant to the outcome of this case.[6] The focus of

---

[5] The fact that a thermostat has been used to control the mold heater does not mean that the mold temperature has been continually *measured*. A thermostat reacts to only one temperature—the one to which it has been set. It is incapable of discretely recognizing the existence of any other definite temperature, and, hence, is incapable of *continually measuring* the temperature of the environment in which it has been placed; it merely knows whether the actual temperature is above or below the set point. This can hardly be called temperature *measurement*.

[6] Although in *Flook* the Supreme Court assumed the equation of the claim to be old in the art even though it was not, the holding of that case does not depend on that mode of analysis. Since Flook's claims were held to be directed to methods of calculation, they were nonstatutory *regardless* of whether the equation was new or old. While the Supreme Court in that case may have found that analysis a convenient vehicle to highlight the fact that Flook's actual contribution to the useful arts was his new formula, we do not believe the

the inquiry should be whether the claim, *as a whole*, is directed essentially to a method of calculation or mathematical formula. No one step or subgroup of steps determines whether the entire claim defines statutory subject matter. *Flook*, 437 U.S. at 594 n. 16, 198 USPQ at 199 n. 16; *In re Chatfield*, 545 F.2d at 158, 191 USPQ at 738. We are concerned only with what *entire* claims define and with whether that falls within § 101.

We turn now to a consideration of the claims on appeal. Appellants attach significance to the fact that claim 11, unlike the remaining claims, does not anywhere recite a computer. In light of our foregoing discussion regarding § 101, we do not find either the presence or absence of computer-related recitations in a claim to be of any significance. If the claim is drawn to a mathematical algorithm, formula, or method of calculation, it is nonstatutory whether it recites that a computer, an abacus, or a pencil and paper are used to make the calculations. The statutory nature of a process or method does not depend, under § 101, on the means used to carry it out. *In re Gelnovatch*, supra, *In re Johnson*, supra.

Since the claims before us directly recite a mathematical formula, namely, the Arrhenius equation, they must be subjected to further scrutiny. The mere presence of a mathematical formula in a claim is not a prima facie ground for holding that claim

---

Court meant to establish that analysis as a general test in determining compliance with § 101, especially when indiscriminately applied to claim limitations generally.

to be nonstatutory, *Flook*, 437 U.S. at 590, 198 USPQ at 197; *In re Johnson*, 589 F.2d at 1076 n. 5, 200 USPQ at 206 n. 5, but, for the claim to be statutory, there must be some substance to it other than the recitation and solution of the equation or formula. The formula, as an embodiment of a scientific principle, must be applied in some useful manner in a method or process, *see, e.g., Tilghman* v. *Proctor*, 102 U.S. 707 (1880) (scientific fact or principle, of which a mathematical formula is one example, used in a chemical process), or be embodied in the design of some useful structure, machine or apparatus, *see, e.g., Eibel Process Co.* v. *Minnesota and Ontario Paper Co.*, 261 U.S. 45 (1923) (law of gravity, expressible in mathematical terms, used in design of a paper-making machine).

This court has formulated a two-step test to determine compliance with § 101 of a claim involving mathematics. *In re Freeman*, 573 F.2d 1237, 1245, 197 USPQ 464, 471 (CCPA 1978). Since, under the first step of the test, the determination that the claim involves mathematical calculations has already been made, we proceed to the second step of the test to determine "whether the claim merely recites a mathematical formula or a method of calculation as in *Benson* and *Flook*." *In re Johnson*, 589 F.2d at 1077, 200 USPQ at 207. We conclude that it does not.

Each of appellants' claims, *as a whole*, recites a process or method for molding rubber articles. They are an improvement over prior processes in that appellants provide for opening the mold at precisely

the correct time rather than at a time which has been determined by approximation or guesswork. It is this feature of the process that *involves* the Arrhenius equation. The recitation of the equation is not separable from the process in which it is used; it is intimately involved in the process, but the claims are not to the equation. We find these claims to be directly comparable to those involved in *Tilghman* v. *Proctor*, supra, and *Eibel Process Co.* v. *Minnesota and Ontario Paper Co.*, supra, in that they involve the employment of a scientific truth to a new and useful end without attempting to control the use of the truth itself. As Mr. Justice Stone, writing for the Court in *Mackay Radio and Telegraph Co.* v. *Radio Corporation of America*, 306 U.S. 86 (1939), stated (306 U.S. at 94):

> While a scientific truth, or the mathematical expression of it, is not patentable invention, a novel and useful structure created with the aid of knowledge of scientific truth may be.

Though he spoke of "structure" the same is true of a process and the reasoning applies with equal force. The claims here at issue are not, as the PTO asserts, directed to an improved method of calculation for the cure time of rubber articles; such a conclusion is only made possible by ignoring the fact that a molding press is recited and operates as the heart of the process. The PTO has separated the claim into old and new elements, ignoring the presence of the old elements in its analysis. Such reasoning is impermissible. The novelty or otherwise of any element

or even of all the elements or steps, or of the combination has no bearing on whether the process is encompassed by § 101.

The claims here on appeal are fundamentally different from the claims involved in *Flook*. They recite a process involving the manipulation of apparatus resulting in the chemical and physical change of starting material, the time that the mold remains closed being controlled by a series of calculations using a recited formula. *See In re Deutsch*, 553 F.2d 689, 193 USPQ 645 (CCPA 1977) (claimed methods of operating an entire manufacturing plant system using particular algorithms); *In re Chatfield*, supra (claimed methods of operating machines in a more efficient manner using particular algorithms). It would be a gross distortion to say that the claims on appeal are directed essentially to calculations. In *Flook*, by contrast, the claims recite nothing but the calculation, coupled with the post-solution activity consisting only of updating an alarm limit to the newly-calculated value which is merely a new number. Here, the calculation is intimately entwined with the rubber molding process recited. Therefore appellants are not claiming a process for merely generating a new number by a calculation.

Stated as a general proposition, "regardless of claim format" as the board said, one would hardly question that a rubber-molding process falls within the § 101 categories of possibly patentable subject matter, and that is what is claimed. We see no reason why particularizing in claims a more precise

way of timing the molding cycle should remove them from the "process" category of § 101. The board erred in ignoring all of the old or conventional steps in the claims. Novelty considerations have no bearing on whether claims define statutory subject matter under § 101.

The decision of the board is *reversed.*

REVERSED

APPENDIX B

UNITED STATES COURT OF CUSTOMS AND PATENT APPEALS

MANDATE

No. 79-527

IN THE MATTER OF THE APPLICATION OF
JAMES R. DIEHR, II and THEODORE A. LUTTON

Serial No. 602,463

ON APPEAL FROM THE BOARD OF APPEALS

This CAUSE having been heard and considered, it is

ORDERED and ADJUDGED: Reversed.

DATED August 9, 1979
Petition for rehearing denied; October 18, 1979.

A TRUE COPY

TEST:

GEORGE E. HUTCHINSON
Clerk
United States Court
of Customs and
Patent Appeals

Certified this 25th day of
October 1979

By /s/ George E. Hutchinson

[SEAL]

APPENDIX C

OPINION AND DECISION OF BOARD OF APPEALS, AUGUST 18, 1978

Before Burns and Spencer, Examiners-in-Chief, and Craig, Acting Examiner-in-Chief.

Burns, Examiner-in-Chief.

This is an appeal from the final rejection of claims 1 through 11, constituting all of the claims presently in the case. Disclosure is directed to a method of operating a rubber-molding press, best understood from a consideration of representative claim 1:

> 1. A method of operating a rubber-molding press for precision molded compounds with the aid of a digital computer, comprising:
>
> providing said computer with a data base for said press including at least,
>
> natural logarithm conversion data (ln),
>
> the activation energy constant (C) unique to each batch of said compound being molded, and
>
> a constant (x) dependent upon the geometry of the particular mold of the press,
>
> initiating an interval timer in said computer upon the closure of the press for monitoring the elapsed time of said closure,
>
> constantly determining the temperature (Z) of the mold at a location closely adjacent to the mold cavity in the press during molding,
>
> constantly providing the computer with the temperature (Z),

repetitively calculating in the computer, at frequent intervals during each cure, the Arrhenius equation for reaction time during the cure, which is

$$\ln v = C Z + x$$

where v is the total required cure time,

repetitively comparing in the computer at said frequent intervals during the cure each said calculation of the total required cure time calculated with the Arrhenius equation and aid elapsed time, and

opening the press automatically when a said comparison indicates equivalence.

A single rejection has been lodged against the claims under 35 U.S.C. 101, the examiner maintaining that the claims are directed to non-statutory subject matter. We have reviewed the arguments advanced by appellants in their brief and reply brief, together with the statement of the rejection and response provided by the examiner in his final rejection and answer. We agree with the examiner.

Beginning on page 22 of their brief, appellants urge that their application does not disclose a computer program and that, thus, they could not claim one. They point to the several preambles of the independent claims 1, 5, 7 and 11. While we might agree that appellants have provided no program listing as part of their disclosure, we would observe that there are many ways in which a program may be disclosed. Figures 3-A and 3-B, with the attendant textual description on pages 9-13 of the specifica-

tion, are, we think, an appropriate description of a program sufficient for the person of ordinary skill in the art to create the machine readable program code acceptable to the computer. This appears to be substantiated by the affidavit of Ekland submitted by appellants, and we note that no rejection under 35 U.S.C. 112, paragraph 1, as to insufficiency of the disclosure has been urged by the examiner.

We have reviewed the cases cited by appellants, in particular *Gottschalk* v. *Benson et al.*, 409 US 63, 175 USPQ 673 (1972), hereinafter Benson, and *In re Christensen*, 478 F.2d 1392, 178 USPQ 35 (CCPA, 1973). We have also had available for consideration the newly decided case by the USSC, *Parker* v. *Flook*, 437 US . . . ., 198 USPQ 193 (1978), hereinafter Flook.

Turning to the claims, we agree with appellants that steps are included which are not part of a computer program. We take exception, however, to appellants' arguments on pages 28 and 29 of the brief as to what constitutes part of a computer program.

In claim 1, the only non-programming step which we perceive is:

> "constantly determining the temperature (Z) of the mold . . .".

This step, we note, appears to be within the prior art as described in "Background of the Invention", specification pages 1-3.

Steps found in the prior art such as these will not lift the Benson/Flook proscription, *In re* Christensen,

supra; In re Chatfield, 545 F.2d 152, 191 USPQ 730 (CCPA, 1976); and *In re Richman*, 563 F.2d 1026, 195 USPQ 341 (CCPA, 1977).

The step of "opening the press automatically . . ." appears to fall in the post-solution category which will not render the claims statutory, see Flook. We would add that proper execution of such a step requires the appropriate program instructions in the recited preceding steps, and thus may be considered as program dependent.

Steps, such as those of claim 1, which provide the computer with data base or with signals representing parameters sensed, such as:

> "constantly providing . . . (Z)", or
> "initiating an interval timer in said computer . . .",

all require instructions written into the program without which the computer will not accept data or initiate any of its internal timers.

That appellants' system performs operations involving an algorithm, solving a mathematical problem, as addressed in Benson and Flook, is apparent, see for example claim 1 "repetitively calculating . . ." and "repetitively comparing . . ."

In claims 2 and 8, "measuring . . ." appears to be a non-programming step, but of the data gathering category, while "automatically updating said data base . . ." clearly requires the presence of program instructions.

In claims 3, 4, 9 and 10, the first three steps, namely," providing . . .", "calculating . . .", and "comparing . . ." require programming instructions.

The step of "controlling . . .", found in claims 3 and 9, is post-solution in character and is subject to our remarks above.

As for claims 5 and 6, all of the steps require program instructions.

With regard to claim 7:

"installing . . .",

"closing said press . . .",

"constantly determining the temperature . . .",

"opening the press . . .", and

"removing . . . article",

all appear to be conventional steps known in the art. The remainder of the steps in this claim are directed to the computer program.

In claim 11, steps (a), (b), (c), (e), (f), (i) and (j) appear to be conventional molding process steps, while steps (d), (g) and (h) set forth the program.

It is our view that the only difference between the conventional methods of operating a molding press and that claimed in appellants' application rests in those steps of the claims which relate to the calculation incident to the solution of the mathematical problem or formula used to control the mold heater and the automatic opening of the press.

We think that appellants' contribution, regardless of claim format, is a computer program of the character which the USSC has indicated, in both Flook and Benson, is outside the bounds of 35 U.S.C. 101.

We have had occasion to make reference, severally, to the steps of the claims which represent prior art,

and also to the steps which constitute the computer program. In so doing however, we do not consider that we have in any way dissected the claim. Discussion of the various features or components of the claims would not appear to be inconsistent with the view that a patent claim must be considered as a whole, see Flook. We will sustain the rejection.

The decision of the examiner is affirmed.

AFFIRMED

WALTER W. BURNS, JR.
Examiner-in-Chief

RICHARD A. SPENCER
Examiner-in-Chief

JERRY D. CRAIG
Examiner-in-Chief
(Acting)

BOARD OF APPEALS

APPENDIX D

U.S. DEPARTMENT OF COMMERCE
Patent and Trademark Office
Address: COMMISSIONER OF PATENTS AND TRADEMARKS
Washington, D.C. 20231

Paper No. 7

Ruggiero 236
08/06/75 602,463
James R. Dierh II, et al

Robert E. Wickersham
Owen, Wickersahm, et al
433 Calif. St., 11th Floor
San Francisco, Calif. 94104

Mailed 1-26-76

This is a communication from the Examiner in charge of your application.

Commissioner of Patents and Trademarks

☑ This application has been examined.

☐ Responsive to communication filed _____ ☐ This action is made final.

A SHORTENED STATUTORY PERIOD FOR RESPONSE TO THIS ACTION IS SET TO EXPIRE 3 MONTH(S) ____ DAYS FROM THE DATE OF THIS LETTER.

PART I

The following attachments(s) are part of this action:

a. ☑ Notice of References Cited, Form PTO-892. b. ☐ Notice of Informal Patent Drawing, PTO-948.

c. ☐ Notice of Informal Patent Application, Form PTO-152. d. ☐

PART II

Summary of Action

1. ☑ Claims 1-10 are presented for examination.
2. ☐ Claims _____ are allowed.
3. ☐ Claims _____ would be allowable if amended as indicated.
4. ☑ Claims 1-10 are rejected.
5. ☐ Claims _____ are objected to.
6. ☐ Claims _____ are subject to restriction or election requirement.
7. ☐ Claims _____ are withdrawn from consideration.
8. ☐ Since this application appears to be in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under Ex parte Quayle, 1935 C.D. 11; 453 OG. 213
9. ☐ Since it appears that a discussion with applicant's representative may result in agreements whereby the application may be placed in condition for allowance, the examiner will telephone the representative within about 2 weeks from the date of this letter.
10. ☐ Receipt is acknowledged of papers under 35 USC 119, which papers have been placed of record in the file.
11. ☐ Applicant's claim for priority based on an application filed in _____ on _____ is acknowledged. It is noted, however, that a certified copy as required by 35 USC 119 has not been received.
12. ☐ Other

PTOL 326 (7/73)

1. This application has been examined and this action is responsive to applicant's preliminary amendment filed along with the application.

2. The specification is objected to as containing insufficient disclosure under 35 USC 112. The instant invention is disclosed and claimed to be one involving a general purpose digital computer properly programmed to calculate the correct cure time for a rubber-molding press and to open such press accordingly. A general purpose computer by itself would be incapable of carrying out any operation until its sequence of internal interconnections has been added thereto by the preparation and loading of a program into the internal memory of the computer. The instant disclosure does not identify any program which will cause the computer to carry out the necessary functions. Although applicants have provided a flow chart, it is noted that such flow chart is not a program and only suggests operations from the point of view of desired results.

3. Claims 1-10 are now in this case.

4. Claims 1-10 are rejected as being drawn to insufficient disclosure as discussed in paragraph 2, above.

5. Claims 1-10 are further rejected under 35 USC 101 as being drawn to non-statutory subject matter. Claims 1-6 recite a series of steps for operating a rubber molding press in conjunction with a digital computer. A close inspection of the claims reveals that all of the claimed method steps involve either

the inputting of data *to* the computer, the operation of the computer on such data, and the provision of an output signal by the computer in response to such operation. All of these steps are carried out by the computer under control of a stored program. New claims 7-10 recite the additional "physical" steps of installing rubber in the press and the subsequent closing of the press; however, these steps are conventional and necessary to the process and cannot be the basis of patentability. It remains the Examiner's position therefore, that applicants' claims define and seek protection on a computer program for operating a rubber molding press. Such has been held to be non-statutory subject matter by the Supreme Court in Gottschalk v. Benson, 175 USPQ 673.

6. Applicants' arguments have been considered but are not convincing to overcome the above rejections. In patent application S. N. 472,595, applicants submitted a Rule 132 affidavit which detailed a factory installation of the invention involving 60 presses and concluded that the time required to achieve production would be 7 months. In response to the Examiner's position that such a time span for implementation of the invention was outside the bounds of "undue experimentation", the applicants have filed an additional Rule 132 affidavit. This affidavit includes an estimate of a 6 man week time span for implementation of the invention if only a single press were involved. However, it must be pointed out that such an estimate is merely an opinion and few if any facts have been presented to support such a con-

clusion. The Examiner remains of the position that such evidence is not sufficient to overcome the rejection on insufficient disclosure.

7. Patents A-E are cited of interest but are not applied against the claims.

/s/ Joseph F. Ruggiero
JOSEPH F. RUGGIERO
Examiner
Group Art Unit 236

Ruggiero/dmcb
557-2871
12/2/75

FORM PO-892 (REV. 2-72) U.S. DEPARTMENT OF COMMERCE PATENT OFFICE

SERIAL NUMBER	GROUP ART UNIT	ATTACHMENT TO PAPER NUMBER
472595	236	

NOTICE OF REFERENCES CITED

☐ Check here if this is a supplemental citation. (Do not prepare an additional folder.)

APPLICANT(S): J. R. DIEHR ET AL

U.S. PATENTS

*		PATENT NO.	DATE	PATENTEE	CLASS	SUB-CLASS	FILING DATE IF APPROPRIATE
	A	3659974	5-1972	NEUGROSCHL	264	40 X	
	B	3721721	2-1973	GOULD ET AL	264	40	
	C	3819915	6-1974	SMITH	235	151 X	8-17-1971
	D	3579626	5-1971	BRITTAIN	264	315 X	
	E	3649729	3-1972	DAVIS ET AL	264	40	
	F						
	G						
	H						
	I						
	J						
	K						

FOREIGN PATENTS OR PUBLISHED APPLICATIONS

*		PATENT NO.	DATE	COUNTRY	NAME	CLASS	SUB-CLASS	PERTINENT SHTS. DWG	PERTINENT PP. SPEC.
	L								
	M								
	N								
	O								
	P								
	Q								

OTHER REFERENCES (Including Author, Title, Date, Pertinent Pages, Etc.)

*		
	R	
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EXAMINER	DATE	
RUGGIERO	11-18-1975	☐ CHECK HERE IF FOREIGN EXCHANGE

* ATTENTION R.P.S.: Do not furnish copy if this box is checked.

USCOMM-DC 50880-P71

LETTER OF EXAMINER, JANUARY 26, 1976

[X] This application has been examined.
[ ] Responsive to communication filed .....
[ ] This action is *made final.*

A SHORTENED STATUTORY PERIOD FOR RESPONSE TO THIS ACTION IS SET TO EXPIRE 3 MONTHS(S) ..... DAYS FROM THE DATE OF THIS LETTER.

PART I

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a. [X] Notice of References Cited, Form PTO-892.
b. [ ] Notice of Informal Patent Drawing, PTO-948.
c. [ ] Notice of Informal Patent Application, Form PTO-152.
d. [ ]

PART II

Summary of Action

1. [X] Claims 1-10 are presented for examination.
2. [ ] Claims ..... are allowed.
3. [ ] Claims ..... would be allowable if amended as indicated.
4. [X] Claims 1-10 are rejected.
5. [ ] Claims ..... are objected to.
6. [ ] Claims ..... are subject to restriction or election requirement.
7. [ ] Claims ..... are withdrawn from consideration.

8. [ ] Since this application appears to be in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under Ex parte Quayle, 1935 C.D. 11; 453 OG. 213.

9. [ ] Since it appears that a discussion with applicant's representative may result in agreements whereby the application may be placed in condition for allowance, the examiner will telephone the representative within about 2 weeks from the date of this letter.

10. [ ] Receipt is acknowledged of papers under 35 USC 119, which papers have been placed of record in the file.

11. [ ] Applicant's claim for priority based on an application filed in ..... on ..... is acknowledged. It is noted, however, that a certified copy as required by 35 USC 119 has not been received.

12. [ ] Other

1. This application has been examined and this action is responsive to applicant's preliminary amendment filed along with the application.

2. The specification is objected to as containing insufficient disclosure under 35 USC 112. The instant invention is disclosed and claimed to be one involving a general purpose digital computer properly programmed to calculate the correct cure time for a rubber-molding press and to open such press accordingly. A general purpose computer by itself would be incapable of carrying out any operation until its sequence of internal interconnections has been added

thereto by the preparation and loading of a program into the internal memory of the computer. The instant disclosure does not identify any program which will cause the computer to carry out the necessary functions. Although applicants have provided a flow chart, it is noted that such flow chart is not a program and only suggests operations from the point of view of desired results.

3. Claims 1-10 are now in this case.

4. Claims 1-10 are rejected as being drawn to insufficient disclosure as discussed in paragraph 2, above.

5. Claims 1-10 are further rejected under 35 USC 101 as being drawn to non-statutory subject matter. Claims 1-6 recite a series of steps for operating a rubber molding press in conjunction with a digital computer. A close inspection of the claims reveals that all of the claimed method steps involve either the inputting of data *to* the computer, the operation of the computer on such data, and the provision of an output signal by the computer in response to such operation. All of these steps are carried out by the computer under control of a stored program. New claims 7-10 recite the additional "physical" steps of installing rubber in the press and the subsequent closing of the press; however, these steps are conventional and necessary to the process and cannot be the basis of patentability. It remains the Examiner's position therefore, that applicants' claims define and seek protection on a computer program for operating a rubber molding press. Such has been held to be

non-statutory subject matter by the Supreme Court in Gottschalk v. Benson, 175 USPQ 673.

6. Applicants' arguments have been considered but are not convincing to overcome the above rejections. In patent application S. N. 472,595, applicants submitted a Rule 132 affidavit which detailed a factory installation of the invention involving 60 presses and concluded that the time required to achieve production would be 7 months. In response to the Examiner's position that such a time span for implementation of the invention was outside the bounds of "undue experimentation", the applicants have filed an additional Rule 132 affidavit. This affidavit includes an estimate of a 6 man week time span for implementation of the invention if only a single press were involved. However, it must be pointed out that such an estimate is merely an opinion and few if any facts have been presented to support such a conclusion. The Examiner remains of the position that such evidence is not sufficient to overcome the rejection on insufficient disclosure.

7. Patents A-E are cited of interest but are not applied against the claims.

JOSEPH F. RUGGIERO
Joseph F. Ruggiero
Examiner
Group Art Unit 236

LETTER OF EXAMINER, JULY 8, 1976

[X] This application has been examined.

[X] Responsive to communication filed April 21, 1976.

[X] This action is *made final.*

A SHORTENED STATUTORY PERIOD FOR RESPONSE TO THIS ACTION IS SET TO EXPIRE 3 MONTH(S) . . . . DAYS FROM THE DATE OF THIS LETTER.

PART I

The following attachment(s) are part of this action:

a. [ ] Notice of References Cited, Form PTO-892.

b. [ ] Notice of Informal Patent Drawing, PTO-948.

c. [ ] Notice of Informal Patent Application, Form PTO-152.

d. [ ]

PART II

Summary of Action

1. [X] Claims 1-11 are presented for examination.

2. [ ] Claims ..... are allowed.

3. [ ] Claims ..... would be allowable if amended as indicated.

4. [X] Claims 1-11 are rejected.

5. [ ] Claims ..... are objected to.

6. [ ] Claims ..... are subject to restriction or election requirement.

7. [ ] Claims ..... are withdrawn from consideration.

8. [ ] Since this application appears to be in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under Ex parte Quayle, 1935 C.D. 11; 453 OG. 213.

9. [ ] Since it appears that a discussion with applicant's representative may result in agreements whereby the application may be placed in condition for allowance, the examiner will telephone the representative within about 2 weeks from the date of this letter.

10. [ ] Receipt is acknowledged of papers under 35 USC 119, which papers have been placed of record in the file.

11. [ ] Applicant's claim for priority based on an application filed in ..... on ..... is acknowledged. It is noted, however, that a certified copy as required by 35 USC 119 has not been received.

12. [ ] Other

1. This action is responsive to applicant's communication filed April 21, 1976.

2. Claims 1-11 are now in this case.

3. Claims 1-11 are rejected under 35 USC 101 as being drawn to non-statutory subject matter as discussed in paragraph 5, paper no. 2. New claim 11 is subject to the same deficiencies as claims 7-10 in that the so-called "physical" steps such as heating the

mold, closing the press, heating the mold and opening the press are conventional and necessary to the process and cannot be the basis for patentability.

4. Applicant's arguments have been considered but are not convincing. As applicants correctly state, the Supreme Court in the case of Dann v. Johnston, decided the case on the issue of obviousness under 35 USC 103 and did not discuss the issue raised by 35 USC 101. However, the Examiner cannot agree with applicant's conclusion that such action results in an implication that the Court was somehow acquiescing in the CCPA position on 35 USC 101. The Supreme Court's decision was actually a reversal of the CCPA decision which leaves standing the Board of Appeals decision regarding the patentability of the claims, i.e. that the claims are not patentable.

5. This action is made FINAL.

JOSEPH F. RUGGIERO
Joseph F. Ruggiero
Examiner
Group Art Unit 236

APPENDIX E

APPLICATION OF JAMES R. DIEHR, II AND THEODORE A. LUTTON, FILED AUGUST 6, 1975, SERIAL NUMBER 602,463, FOR DIRECT DIGITAL CONTROL OF RUBBER MOLDING PRESSES

Abstract of the Disclosure

Rubber-molding presses, which are closed manually upon installation of pieces of rubber compound, are opened automatically by a system which continuously calculates and recalculates the correct cure time and is actuated when the calculated cure time equals the elapsed cure time. An interval timer starts running from the time of mold closure, and the temperature within the mold cavity is measured often, typically every ten seconds. The temperature is fed to a computer which also is given access to the time-temperature cure data for the compound being molded, and the computer calculates and recalculates every time the data as to temperature is presented, until the total picture of time and temperature presents to the computer the time at which the material is fully cured. Then the computer signals for automatic opening of the mold press. Many presses can be controlled by a single computer, which still operates to recalculate the data about every ten seconds, and the time-temperature cure data for the compound can also be modified by information from a rheometer.

Cross Reference to Related Application

This application is a continuation-in-part of application Serial No. 401,127, filed September 26, 1973.

Background of the Invention

This invention relates to accurate and automatic control of the molding time for rubber compounds and the automatic opening of rubber-molding presses when the cure is calculated to be complete.

Much time-temperature cure data for rubber compounds is known, and each manufacturer of rubber products usually has some of this material at his disposal. The usual way of operating rubber-molding presses is for the operator to load them manually and for the operator then to close the press. Closure of the press operates a timer which has been preset for a time at which cure should be completed in view of what is supposed to be the temperature of the mold. However, the mold temperature, even though it is thermostatically maintained, is not likely to be identical with this supposed temperature. The actual temperature of the mold may vary rather widely, and the correction of the temperature by the thermostat may take some time. For example, the amount of time that the press is open during the operator's loading of the press varies, and the longer the press is open, the cooler the mold is when it is closed and again starts heating. Thus, it may be many degrees below its nominal temperature when the mold is first closed, and it may take a substantial amount of time

for the mold to reach this nominal temperature. The thermostats are usually actuated within a plus or minus 2% to cause the device to heat until it reaches the nominal temperature, but this is not sufficient to assure that that temperature has been maintained as an average during the entire molding operation—as a matter of fact, it rarely if ever has.

Because of these inaccuracies, the practice in the industry has been to calculate the cure time as the shortest time in which one can be absolutely certain that all parts will be cured with any reasonable amount of mold-opening time during unloading of the previous batch and reloading. This, of course, means that the rubber will tend to be overcured in almost every instance, because the worst cure time will not be so often met with. It also means that if there are times in which the mold is opened longer than was thought or in which the mold temperature for some other reason did not rise in time, that even the nominally worst time will not be so bad that some batches will be undercured.

This practice has had two serious economical effects: in the first place, many batches have to be discarded when after tests they are found either to be undercured or overcured beyond the tolerance limits. This has been a serious problem in many factories where synthetic rubber has been cured. In the second place, it means that the molds are kept occupied and are closed much longer than they need to be to obtain the best results. This means that fewer products can be molded per unit time and per hour of operator

work. As a result, there has been substantially less production than would have been possible had the actual cure time been known and followed by the mold.

It is an object of the present invention to achieve more exact cure of the rubber material being molded so as to substantially reduce the number of defectively cured batches that have to be rejected. Another object is to reduce substantially the amount of time in which the presses are closed unnecessarily. By accurate and constant calculation and recalculation of the correct mold time under the temperatures actually present in the mold, the material can be cured accurately and can be relied upon to produce very few rejections, perhaps completely eliminating all rejections due to faulty mold cure. Furthermore, the mold and the operator can be much more efficiently employed.

Summary of the Invention

The invention uses computers of well-known type with data storage banks containing the time-temperature cure data for the compound or compounds being used; in some cases, the stored data includes additional cure data, such as variations in batch characteristics. A surveillance system is maintained over the mold to determine the actual mold temperature substantially continuously, for example, every ten seconds, and to feed that information to the computer along with the pertinent stored data and along with the elapsed time information. The computer then

continually recalculates on the basis of the temperature changes, and the elapsed time, and the time-temperature cure data, and arrives every ten seconds at a new time-temperature cure curve for that particular batch then being cured which the computer compares with the elapsed time every second; then, when the calculated cure time equals the elapsed cure time, the computer signals the opening of the mold to an electromechanical device which immediately opens the mold.

Modern computers act so rapidly that these recalculations are no burden and can easily be done each second. In fact, a computer can work much faster than that, so that a series of molds can be monitored in the same way with perhaps 50 or 60 molds being watched, and every ten seconds the actual temperature for each mold involved can be fed to the computer, which calculates with the time-temperature data available the correct cure for each and every mold and opens each one separately.

Moreover, further accuracy can be obtained by supplying the computer with rheometer data for each batch of the molding compound so that the computer has even more accurate information that will affect the time-temperature cure data.

Other objects and advantages of the invention will appear from the following description of a preferred embodiment.

Brief Description of the Drawings

In the drawings:

Fig. 1 is a flow sheet for a simple system for controlling a single mold and a single compound and illustrating the principles of the invention.

Fig. 2 is a flow sheet for a more complex system in which many molds are controlled by the same computer and in which a rheometer test is made for each batch of compound.

Fig. 3 is a program flow chart for the method illustrated in the flow sheet of Fig. 2.

Fig. 3 is shown on two sheets as Figs. 3A and 3B.

Description of Some Preferred Embodiments

A simple case involving a single mold:

The invention will probably best be understood by first describing a simple example, in which a single mold is involved and in which the information is relatively static.

The invention is applicable to a wide range of synthetic elastomers being cured and to their being molded for many uses. Much of the data verifying the invention has been obtained in the manufacture and cure of synthetic elastomer radial shaft seals. Butyl rubbers, acrylic rubbers and others have been concerned. The tests have shown that the method works on all of them.

A standard digital computer may be employed in this method. It has a data storage bank of suitable size which, of course, may vary when many molds are

used and when more refinements are employed. However, Fig. 1 shows a relatively simple case which achieves results that are vast improvements over what has been done up to now. Thus, in the manufacture of synthetic elastomer oil seals, some actual data showed that about 12.2% of time could be saved by using this invention; in other words, the molds could be in use for 12.2% more time than they had been theretofore. These data also showed that the percent rejects could be reduced by about 45% in this particular plant.

The data bank of the computer is provided with a digital input into which the time-temperature cure data for the compound involved is fed, as shown in Fig. 1. All the data is available to the computer upon call, by random access, and the call can be automatic depending upon the temperature actually involved. In other words, the computer over and over questions the data storage, asking, what is the proper time of cure for the following summation of temperatures? The question may be asked each second, and the answer is readily provided.

The mold is closed manually, as in the present practice, since this is the best way to assure that everything has been placed properly into the mold. The operator, however, has no other duties than to remove the cured articles from the mold, to put in the "prep" or blanks which are to be molded and cured, to make sure that every cavity is properly filled, and then to close the mold. He does not have to concern himself about the temperatures or cure time, because all that is taken care of automatically.

Once the mold has been closed manually, it initiates a timer in the computer, via a digital signal, which feeds the elapsed time of mold closure to the computer constantly or in a digital fashion. Thus, once each second the computer can be aware of the amount of time involved, and this can be made even more frequent if that is desired. A point of difference from the prior art, however, is that the timer itself does not directly actuate the opening of the mold, and the mold time is not a set time.

The actual mold temperature is fed to the computer on a substantially continuous basis, for example, every ten seconds. Thermocouples, or other temperature-detecting devices, located directly within the mold cavity may read the temperature at the surface where the molding compound touches the mold, so that it actually gets the temperature of the material at that surface. The computer then performs series of integrations to calculate from the series of temperature readings and from the time-temperature cure data a proper cure time and to compare that cure time with the elapsed time. Recalculation continues until the time that has elapsed since mold closure corresponds with the calculated time. Then, the computer actuates the mold-opening device and the mold is automatically opened.

Once again, it should be stressed that the computer is not simply working on one time-temperature curve, it is working on a whole series of them, so that the proper compensation is made for the changes of temperature that occur within the mold. This

makes it possible to get a substantially exact cure time. Therefore, when the cure is calculated as complete it will be complete.

A more complex system—Fig. 2:

The relatively simple system of Fig. 1 is easily expanded within the capability of many present-day computers. For example, the computer can be used to operate a whole series of molds—50 or 60 molds—each one of them receiving the attention of the computer once a second, at which time the elapsed cure time and the calculated cure time are checked for equality.

Data storage can be expanded by including in the data storage bank the time-temperature cure data for all compounds and for past batches of various compounds. Random access enables the data for any particular compound to be made available to the computer upon request, which the computer makes when it is told what compound is being used.

Furthermore, the rheometer test can be made for each batch of the compound to determine the minimum torque and maximum torque as well as intermediate torque levels and temperature, all of which are used to determine cure time in accordance with the Arrhenius equation as explained hereinbelow. This means that each batch can be differentiated and corrections made on the basis of data in the data storage bank which the computer has access to, so that the rheometer data for the batch are fed into the computer each time a new batch is being used in the

system. Thus the constant C referred to below is determined for each particular batch of compound being cured. It can even be used for different batches used in different parts of the same plant, that is, in different molds; the computer can take care of that, too, all within well-known capabilities.

Another factor which affects the time and temperature of curing is that of the mold geometry, and particularly the maximum thickness of the element to be molded. This factor is set out as constant x referred to hereinbelow, and for each mold and compound such data is fed into the computer to enable the computer to calculate the Arrhenius equation. The rule here is that the thickest part of the molded compound has to be completely cured. Knowing the thickest part and the dimensions of it, the results can be much more accurate than otherwise.

Thus, in the system of Fig. 2, each time a mold is closed, even though it is a different time from the closure of every other mold, it starts an elapsed timing situation within the computer per the time-temperature curve and in accordance with the actual mold temperature for each mold. With this information and the other information already mentioned, the computer continuously, for example, every ten seconds, recalculates the proper time-temperature cure and arrives at the cure time, as before stated. When this cure time for the integrated series equals the elapsed time, then each mold is separately opened at its proper elapsed time on the signal from the computer.

Fig. 3 shows a computer program flow chart for the system illustrated in Fig. 2. In Fig. 3 the computer function steps are indicated within rectangles, whereas the logic steps or questions are shown within diamond-shaped parallelograms. A timer-based interrupt 11 initiates the program once every second. Upon program initiation, the computer scans and retrieves from data storage within the computer certain operating data for the first press in the sequence of presses controlled by the computer. This function step, indicated by reference numeral 12, makes available data concerning the press mold configuration constant, the activation energy constant for the material being cured, the mold temperature set point, the constant of proportionality required to determine a temperature control range, and the total elapsed time, if any, that the press has been closed up to the instant of this step. Having available the foregoing information, the computer reaches a logic decision 21, whether the press is closed. If the press is not closed, i.e., the press is open, the program sequences directly to a calculation 41 of temperature control range data, to be subsequently discussed. If the press is closed, a program subroutine to control cure time is followed.

In this subroutine, the computer first updates at 31 the amount of time that this particular press has been closed. Next, the current mold temperature is measured at 32 by thermocouple or other heat sensing means within the mold and the measurement is converted to digital information and read by the com-

puter. The total elapsed closure time and the current temperature, along with the data previously retrieved from data storage are then used by the computer at 33 to calculate the total press closure cure time as a function of the Arrhenius equation:

$$\ln v = C Z + x$$

In this equation:

ln is the symbol for natural logarithm,

v is the total required cure time and end point for press closure.

C is the activation energy constant, a unique figure for each batch of each compounded being molded, determined in accordance with the present invention by rheometer measurements of the batch,

Z is the present mode temperature at 32, and

x is a constant dependent upon the geometry of the particular mold of the press.

This Arrhenius equation is numerically solved as follows:

$$v = e\ (cz + x)$$
$$= 1 + \frac{(cz + x)}{1\ !} + \frac{(cz + x)^2}{2\ !} + \frac{(cz + x)^3}{3\ !}$$

Once a value for *v*, the end point time has been calculated, the computer determines at 34 whether the total elapsed time as updated at 31 is equal to or greater than the calculated end point time. If the updated time at 31 equals or exceeds the calculated end point time at 33, then a control signal is generated at 35 to open the press automatically, thereby completing one scan of the press closure control sub-

routine. If this time has not yet been reached, the subroutine is for the moment completed and the program continues, but the subroutine will be repeated later, usually about once per second.

Whether the full cure time has not been reached or whether it has, the next step is the calculation at 41 of mold temperature control range data. This step may be performed as a subroutine in each scan of the press, or preferably, it may be performed with every tenth scan, or once every ten seconds. The calculation of the mold and temperature control range data is accomplished pursuant to the following Algorithm:

$$\text{Heater on/off state} = \text{Signum}\left|e(t) - K\right|$$

wherein

e(t) is the difference between the mold temperature set point and the present mold temperature and

K is a constant of proportionality set to provide the desired proportional control of the heater.

The computer next determines at 42 whether the mold heater current temperature is beyond the calculated temperature control range. If the current temperature is too high, a signal is generated at 43 to turn the mold heater off. Likewise, if the current mold temperature is too low, a control signal is generated at 43 to turn the mold heaters on. In this manner, the computer maintains close control over actual mold temperature to maintain it within a range of temperatures closely approaching and equalling the set point temperature.

The program next causes the computer to ascertain at 51 whether any change in batch data from the rheometer connected to the computer is awaiting transfer to storage. If new batch data are awaiting transfer to data storage update, the computer passes these update data at 62 to the correct storage address within the computer.

From time to time, new data concerning press mold configuration, batch characteristics, and other system parameters are entered manually by the computer control operator through a control console. Thus, on each program cycle, the computer determines at 61 whether any new data concerning the press are awaiting entry from the console. In the event of new console data, the computer then acts at 62 to transfer the data to the correct storage address within the computer data storage.

Finally, the program asks the computer to determine at 71 whether the press being controlled at the moment is the last press in the total program control sequence. If the press is the last one, the computer waits at 73 for the next program control sequence to be initiated by the timer-based interrupt 11. In other words, the presses are open for product delivery and reloading. However, if another press is to be scanned and controlled within the present program control sequence, the computer proceeds at 72 to act for all such presses and repeats the above-described program routine for those presses, commencing with step 12. With the speed and capacity of presently available computers it is possible to scan and con-

trol as many as sixty different presses within the one-second total program control sequence.

To those skilled in the art to which this invention relates, many changes in construction and widely differing embodiments and applications of the invention will suggest themselves without departing from the spirit and scope of the invention. The disclosures and the description herein are purely illustrative and are not intended to be in any sense limiting.

* * * *

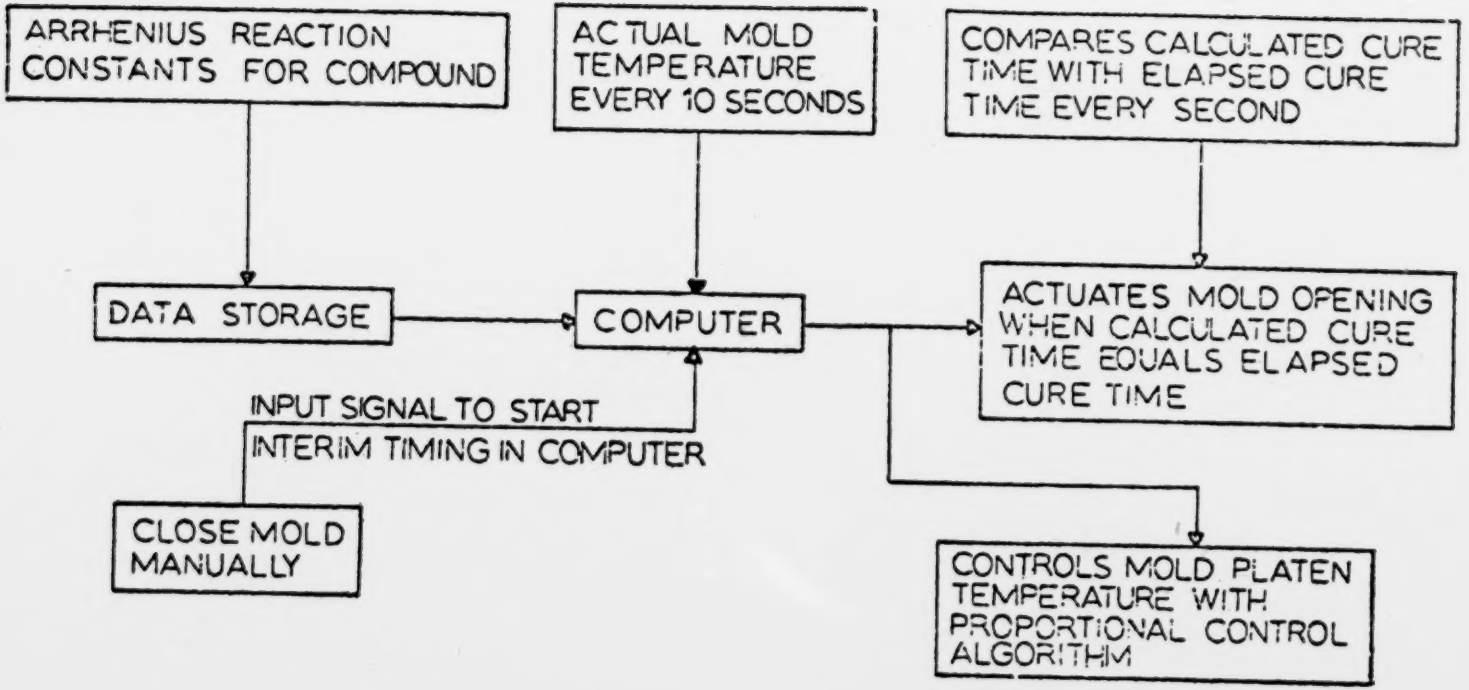

ARRHENIUS REACTION CONSTANTS FOR COMPOUND
ACTUAL MOLD TEMPERATURE EVERY 10 SECONDS
COMPARES CALCULATED CURE TIME WITH ELAPSED CURE TIME EVERY SECOND
DATA STORAGE
COMPUTER
ACTUATES MOLD OPENING WHEN CALCULATED CURE TIME EQUALS ELAPSED CURE TIME
INPUT SIGNAL TO START
INTERIM TIMING IN COMPUTER
CLOSE MOLD MANUALLY
CONTROLS MOLD PLATEN TEMPERATURE WITH PROPORTIONAL CONTROL ALGORITHM
53a

FIG. 1

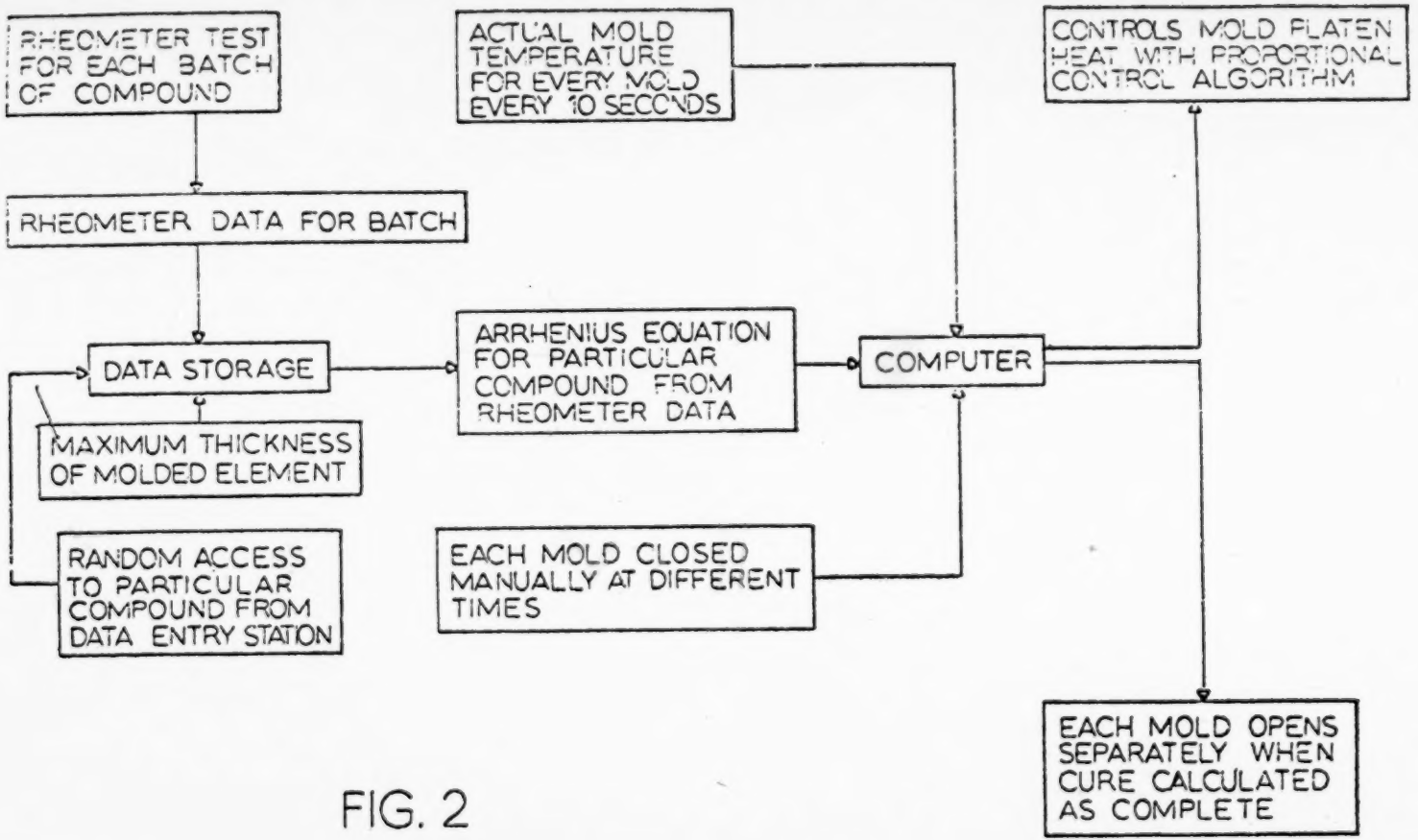

RHEOMETER TEST FOR EACH BATCH OF COMPOUND
ACTUAL MOLD TEMPERATURE FOR EVERY MOLD EVERY 10 SECONDS
CONTROLS MOLD PLATEN HEAT WITH PROPORTIONAL CONTROL ALGORITHM
RHEOMETER DATA FOR BATCH
DATA STORAGE
ARRHENIUS EQUATION FOR PARTICULAR COMPOUND FROM RHEOMETER DATA
COMPUTER
MAXIMUM THICKNESS OF MOLDED ELEMENT
RANDOM ACCESS TO PARTICULAR COMPOUND FROM DATA ENTRY STATION
EACH MOLD CLOSED MANUALLY AT DIFFERENT TIMES
EACH MOLD OPENS SEPARATELY WHEN CURE CALCULATED AS COMPLETE
54a

FIG. 2

FIG. 3-A

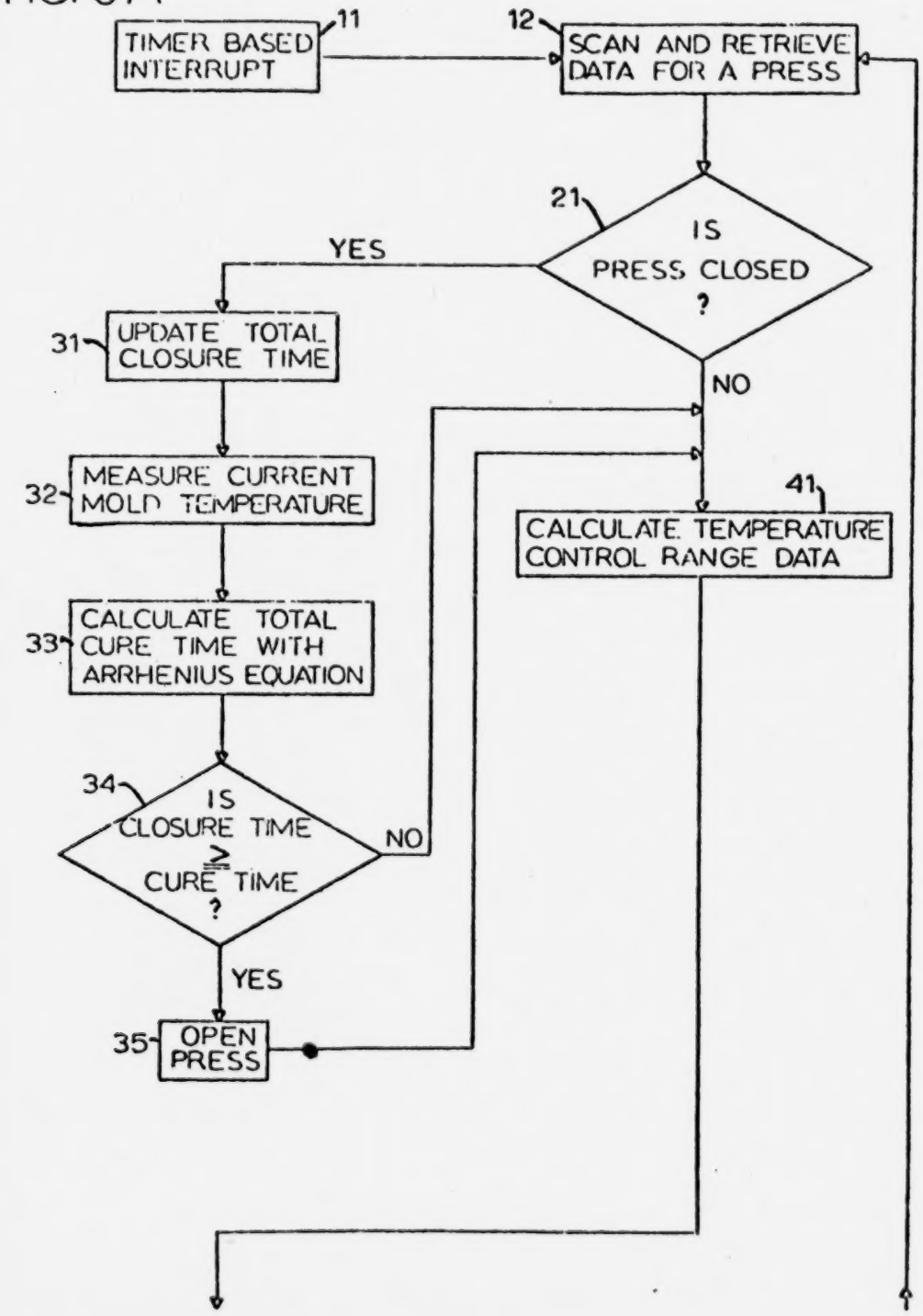
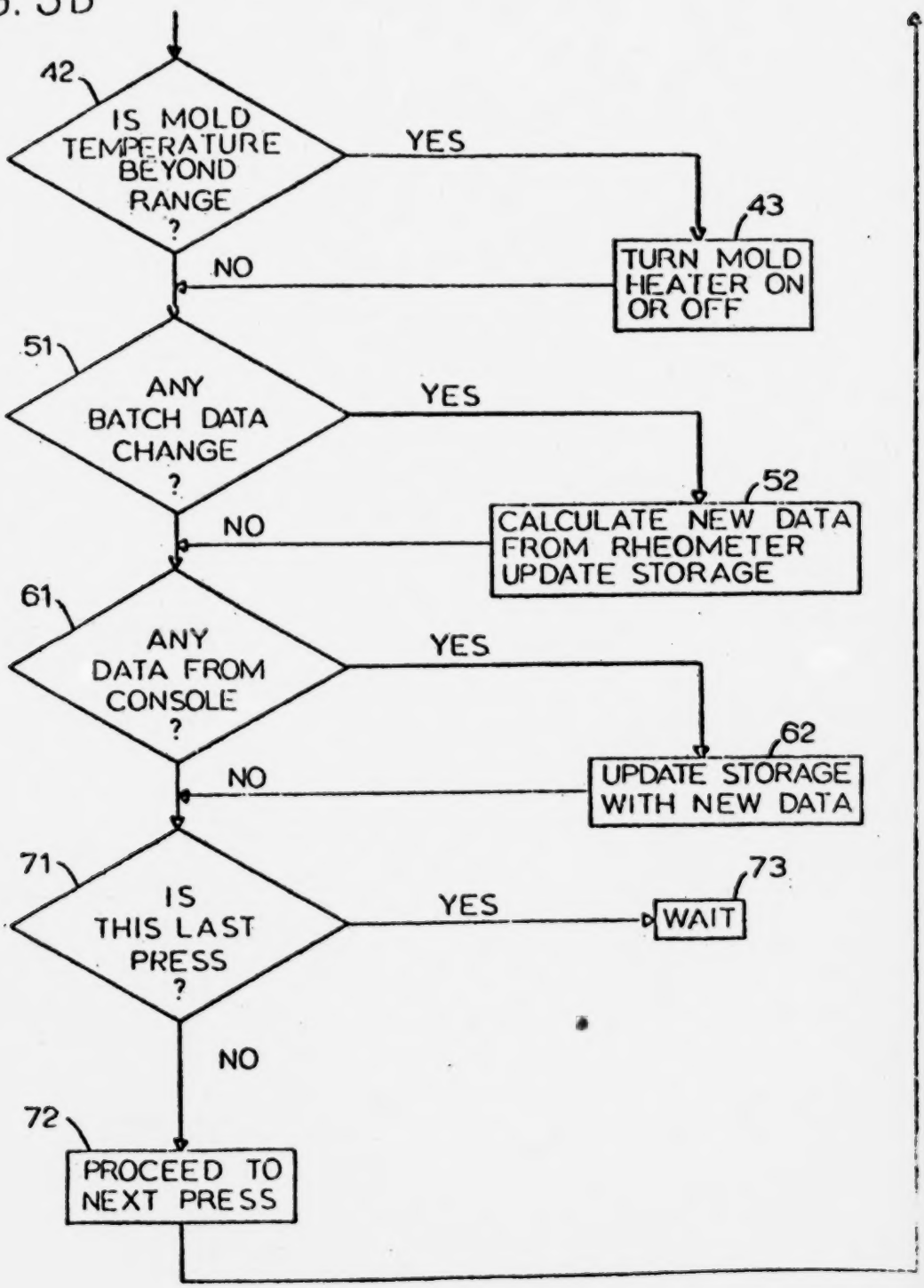

TIMER BASED INTERRUPT
11
12
SCAN AND RETRIEVE DATA FOR A PRESS
21
IS PRESS CLOSED ?
YES
NO
31
UPDATE TOTAL CLOSURE TIME
32
MEASURE CURRENT MOLD TEMPERATURE
33
CALCULATE TOTAL CURE TIME WITH ARRHENIUS EQUATION
34
IS CLOSURE TIME ≥ CURE TIME ?
NO
YES
35
OPEN PRESS
41
CALCULATE TEMPERATURE CONTROL RANGE DATA

FIG. 3-B


42
IS MOLD TEMPERATURE BEYOND RANGE ?
YES
43
TURN MOLD HEATER ON OR OFF
NO
51
ANY BATCH DATA CHANGE ?
YES
52
CALCULATE NEW DATA FROM RHEOMETER UPDATE STORAGE
NO
61
ANY DATA FROM CONSOLE ?
YES
62
UPDATE STORAGE WITH NEW DATA
NO
71
IS THIS LAST PRESS ?
YES
73
WAIT
NO
72
PROCEED TO NEXT PRESS

REJECTED CLAIMS

1. A method of operating a rubber-molding press for precision molded compounds with the aid of a digital computer, comprising:

providing said computer with a data base for said press including at least,

> natural logarithm conversion data (ln), the activation energy constant (C) unique to each batch of said compound being molded, and a constant (x) dependent upon the geometry of the particular mold of the press, initiating an interval timer in said computer upon the

closure of the press for monitoring the elapsed time of said closure.

constantly determining the temperature (Z) of the mold at a location closely adjacent to the mold cavity in the press during molding,

constantly providing the computer with the temperature (Z),

repetitively calculating in the computer, at frequent intervals during each cure, the Arrhenius equation for reaction time during the cure, which is

$\ln v = C Z + x$

where v is the total required cure time,

repetitively comparing in the computer at said frequent intervals during the cure each said calculation of the total required cure time calculated with the Arrhenius equation and said elapsed time, and

opening the press automatically when a said comparison indicates equivalence.

2. The method of claim 1 including measuring the activation energy constant for the compound being molded in the press with a rheometer and automatically updating said data base within the computer in the event of changes in the compound being molded in said press as measured by said rheometer.

3. The method of claim 1 including providing the computer with a mold temperature set point for each mold and a constant of proportionality with which a range of permissible mold temperature variation may be calculated, calculating at frequent periodic intervals in the computer the range of mold temperature variations from the set point, comparing at frequent periodic intervals in the computer the range of mold temperatures and the actual temperature, and controlling the mold heater to keep the mold temperature within the calculated range of the set point.

4. The method of claim 3 wherein the frequent periodic interval is approximately 10 seconds.

5. A method of operating a plurality of rubber molding presses simultaneously curing precision molded compounds in conjunction with a computer, comprising:

providing said computer with a data base for each said press including at least,

> natural logarithm conversion data (ln), the activation energy constant (C) unique to each batch of said compound being molded, and a constant (x) dependent upon the geometry of the particular mold of the said press.

constantly informing the computer of the temperature (Z) of each mold,

informing the computer of the batch of the compound being molded in each mold,

constantly informing the computer of the elapsed time that the compound has been in each mold,

repetitively calculating for each said press at frequent periodic intervals during each cure in the computer the Arrhenius equation to determine the total required cure time, which is $\ln v = C Z + x$, where v is the total required cure time,

repetitively comparing at said frequent periodic intervals in the computer the calculated total required cure time and the elapsed time for each said press, and

opening each said press automatically when its elapsed time has reached its calculated total required cure time.

6. The method of claim 1 wherein each said frequent interval is no longer than approximately one second.

7. A method of manufacturing precision molded articles from selected synthetic rubber compounds with the aid of a digital computer, comprising:

providing said computer with a data base for a molding press to be used in the molding, including at least,

> natural logarithm conversion data (ln), the activation energy constant (C) unique to each batch of said compound being molded, and a constant (X) dependent upon the geometry of the particular mold of the press, installing prepared

unmolded synthetic rubber of one said compound in a molding press cavity,

closing said press,

initiating an interval timer associated with said computer upon the closure of the press for monitoring the elapsed time of said closure,

constantly determining the temperature (Z) of the mold at a location closely adjacent to the mold cavity in the press during molding,

constantly providing the computer with the temperature (Z),

repetitively calculating in the computer, at frequent intervals during each cure, the Arrhenius equation for reaction time during the cure, which is

$\ln v = C Z + x$

where v is the total required cure time,

repetitively comparing in the computer at said frequent intervals during the cure each said calculation of the total required cure time calculated with the Arrhenius equation and said elapsed time,

opening the press automatically when a said comparison indicated equivalence, and

removing the resulting precision molded article from the press.

8. The method of claim 7 including measuring the activation energy constant for the compound being molded in the press with a rheometer and automatically updating said data base within the computer in the event of changes in the compound being molded in said press as measured by said rheometer.

9. The method of claim 7 including in addition,

providing the computer with a mold temperature set point for each mold and a constant of proportionality with which a range of permissible mold temperature variation may be calculated,

calculating at frequent periodic intervals in the computer said range of permissible mold temperature variations,

comparing at frequent periodic intervals in the computer said calculated range of permissible mold temperature variation and the actual temperature (Z) in the press, and

controlling the mold heater from said computer to keep the mold temperature (Z) within said calculated range of the set point.

10. The method of claim 9 wherein the frequent periodic interval is approximately 10 seconds.

11. A method of manufacturing precision molded articles from selected synthetic rubber compounds in an openable rubber molding press having at least one heated precision mold, comprising:

(a) heating said mold to a temperature range approximating a predetermined rubber curing temperature,

(b) installing prepared unmolded syntehtic rubber of a known compound in a molding cavity of predetermined geometry as defined by said mold,

(c) closing said press to mold said rubber to occupy said cavity in conformance with the contour of said mold and to cure said rubber by transfer of heat thereto from said mold,

(d) initiating an interval timer upon the closure of said press for monitoring the elapsed time of said closure,

(e) heating said mold during said closure to maintain the temperature thereof within said range approximating said rubber curing temperature,

(f) constantly determining the temperature of said mold at a location closely adjacent said cavity thereof throughout closure of said press,

(g) repetitively calculating at frequent periodic intervals throughout closure of said press the Arrhenius equation for reaction time of said rubber to determine total required cure time v as follows:

$$\ln v = cz + x$$

wherein c is an activation energy constant determined for said rubber being molded and cured in said press, z is the temperature of said mold at the time of each calculation of said Arrhenius equation, and x is a constant which is a function of said predetermined geometry of said mold,

(h) for each repetition of calculation of said Arrhenius equation herein, comparing the resultant calculated total required cure time with the monitored elapsed time measured by said interval timer,

(i) opening said press when a said comparison of calculated total required cure time and monitored elapsed time indicated equivalence, and

(j) removing from said mold the resultant precision molded and cured rubber article.

APPENDIX F

UNITED STATES PATENT OFFICE

3,718,721

Feb. 27, 1973

METHOD FOR CONTROLLING THE STATE OF CURE OF CURABLE ARTICLES

Inventors: Eric G. Gould; Edward P. Davis, both of c/o Fort Dunlop, Erdington, England

Filed: January 26, 1970

ABSTRACT

A method for controlling the state of cure of at least a part of a curable article during curing in a mould, in which a temperature sensing probe is inserted into a predetermined site in the article and the temperature of the site is monitored as a function of time. The state of cure of the site is computed from the temperature measurements and heating is discontinued when a predetermined state of cure has been reached, of which the following is a specification.

* * * * *

METHOD FOR CONTROLLING THE STATE OF CURE OF CURABLE ARTICLES

This application is a continuation-in-part of our copending application Ser. No. 857,175, filed Sept. 11, 1969, now U.S. Pat. No. 3,649,729, which is a continuation-in-part of Ser. No. 857,642, filed Sept. 10, 1969, now abandoned, which is a streamlined continuation of Ser. No. 640,320, filed May 22, 1967, now abandoned.

This invention relates to the curing of curable articles and is particularly concerned with controlling the state of cure of rubber articles.

In the manufacture of rubber articles, where the article is made from or includes a vulcanizable rubber compound, it is necessary to cure the compound by heating it to effect vulcanization. An optimum state of cure is obtainable for any given rubber compound, the physical properties of the cured rubber being adversely affected by substantial over or under cure.

Over cure or under cure is sometimes obtained on account of variations, during a cure of predetermined duration, in the temperature of the steam utilized for heating moulds within which rubber articles are cured. Variation in the temperature of the mould can also take place due to variation in the ambient temperature, variation in the temperature of the heating media and the transfer of heat therefrom to an article to be cured, the degree of use to which the mould is put, i.e. the amount of heat extracted from the mould per unit time and the period during which the mould is left open between curing operations. It is, therefore, desirable to have a method of or an apparatus for, controlling the state of cure of the article.

According to the present invention, a method of controlling the state of cure of at least a part of a curable article during heat curing thereof in a mould comprises locating a temperature sensing probe at a predetermined site within the article, initiating the cure cycle by supplying heat to the article, monitor-

ing the local temperature of said site as a function of time, computing therefrom the total state of cure of said part of the article as a function of time, and terminating the heat supply when a predetermined state of cure has been reached.

State of cure can be determined in terms of a number of cure units, one cure unit being defined as that cure received at the point under consideration in the article when maintained at a specified reference temperature for 1 minute.

The process of curing is a chemical reaction the rate of which depends on temperature. The relationship between temperature and rate of reaction can be determined experimentally and it can be shown that the relationship can be expressed by the Arrhenius equation thus:

$$t_1/t_2 = \exp[-E/R(1/T_2 - 1/T_1)]$$

where

R 32 Universal gas constant

E = activation energy. This is determined from the slope of a graph of log (time) against the reciprocal of the absolute temperature. A typical figure is 20 K cal/mole

t_1 is the time to desired state of cure at steady temperature T_1

t_2 is the time to the same state or cure at steady temperature T_2

Thus if the time t_1 to reach a desired state of cure at a specified reference temperature T_1 is known, the time to reach the same state of cure at other temperatures can be calculated.

In practical cures the actual rubber temperature is not usually steady. However, the cure time at the reference temperature T_1 equivalent to the actual cure time t_3 during which the temperature has varied can be calculated using a method of numerical integration. This consists of dividing the time-temperature curve for the actual cure into small units of time, d_1, estimating the average temperature during the time interval dt and converting this to the equivalent time of cure at the reference temperature T_1. These small increments of cure are then summed to give the equivalent total cure time at the reference temperature T_1 i.e. the state of cure.
Cure time at

$$T_1 = \sum_{0}^{t_1} \exp.\left(-\frac{E}{R}\left(\frac{1}{T} - \frac{1}{T_1}\right)\right)\mu$$

where T is the mean temperature during each time interval.

Instead of the Arrhenius equation it is possible to use empirical equations which fit the observed data e.g.

$$t_1/t_2 = (T_2 - T_1/CY)$$

where C and Y are constants.

For a selected reference temperature of 287°F, the state of cure at any temperature $T°F$, after an elapsed time of cure of t minutes is expressed as $(t\ C/T\text{-}287/Y)$ cure units, where C and Y are constants. The above expression has been determined experimentally and in one example for natural or synthetic rubber articles, $C = 2.0$ and $Y = 18$.

A third alternative is a polynomiall equation expressing the relationship between the change of properties with temperature and time.

The method of the invention thus renders it possible to calculate the state of cure at the point under consideration at any time in terms of aggregate number of cure units and to terminate the cure when the desired cure corresponding to a predetermined aggregate number of cure units has been obtained. The time of cure which will provide a specified number of cure units, will vary from one article to another sample of the same article, since as the cure temperature unavoidably varies so must the duration of cure to ensure that each article receives an adequate quota of cure units to ensure that the finished cooled article is not substantially over or under cured.

Conveniently the assessment of the relationship of the actual temperature of cure with the predetermined reference temperature of cure is not commenced until a predetermined minimum temperature of the point under consideration is attained, such minimum temperature, in one example, being 210°F., for natural or synthetic rubber materials used in pneumatic tire construction.

The total state of cure may be computed directly by monitoring the local temperature of said site as a function of time. In one instance the local temperature at said site is monitored at set intervals of time and the corresponding increments of cure summated for example by means of a digital computer. In another instance the local temperature at said site is monitored as a continuous function of time, and the

change in total state of cure at every instant is integrated for example by means of an analogue device to give the accumulated state of cure at any instant.

Alternatively the total state of cure may be computed indirectly by monitoring the local temperature of said site as a function of time. The local temperature of said site may be monitored either at set intervals of time or continuously as a function of time, the deviation from a predetermined ideal temperature time variation determined at regular intervals or continuously respectively, and an adequate correction applied by suitable adjustment of the heat supply so that the total state of cure may be computed by reference to the ideal temperature time variation.

The said predetermined state of cure may be less than the state of cure required in the completed article to compensate for the additional curing by the heat remaining in the article after the heat supply has been terminated due to the finite thermal diffusivity of the material of the article.

In addition often it is of advantage to allow the article to remain in the mould after the heat supply has been terminated and until such time as adequate cooling of the article has been achieved to allow the article to cool under controlled conditions. At the end of the cure cycle i.e. after the article has cooled sufficiently the mould is opened either manually or automatically. The latter may be carried out by actuation by the computer of a suitable device operably attached to the mould to open the mould, when the temperature sensing probe registers a suitable temperature.

Preferably the temperature sensing probe is located within the article at a site which after the heat supply has been terminated, has the lowest state of cure.

According to another aspect of the invention, apparatus for controlling the state of cure of at least part of an article during the heat curing thereof in a mould comprises a mould, a mould heating means, a mould cavity defined by the mould, a temperature sensing probe, a substantially rectilinear channel suitably disposed in the wall of the mould, communicating the mould exterior with the mould cavity, and adapted to allow said temperature sensing probe to pass therethrough, monitoring means connected to the temperature sensing probe, for monitoring signals received therefrom as a function of time, computing means cooperating with the monitoring means for computing the total state of cure of the part of the article, and means for rendering the mould heating means inoperative when a predetermined state of cure has been reached.

The temperature sensing probe may be provided with a reinforcing sheath to impart the necessary rigidity thereto.

The said sheath may comprise a metal or alloy of suitable modulus suitable results having been obtained with stainless steel.

It is preferable that the temperature sensing probe comprises a thermocouple although other temperature sensing means e.g. a resistance thermometer, may be adapted to the present application.

It is also preferred that the thermocouple leads are insulated over the length of the temperature sensing probe thus limiting heat transmitted by conduction, from regions of the article or mould not under observation, through the leads to the couple thermo-junction, it being found that mineral insulations are particularly applicable in this respect e.g. magnesium oxide.

Temperature sensing probes may be provided at several different locations in a single article and the signals from all of these fed to a computer which selects only that temperature value which indicates that that point will have the lowest state of cure at the time when the heat supply is terminated.

An alarm system may be provided which is operable if any or all of the factors contributing to a satisfactory cure of the tire deviate substantially from a predetermined range of values.

The invention also includes an article cured by a method or on an apparatus according to the present invention e.g. a pneumatic tire.

* * * *

Having now described our invention what we claim is:

1. A method of controlling the state of cure of at least a part of a curable article during heat curing thereof in a mould comprising locating said article within a mould, said mould including a temperature sensing probe located in a channel extending therethrough, closing said mould and shaping the article against said mould, thereby locating said probe in a

predetermined site within said article, initiating the cure cycle by supplying heat to the article, monitoring the local temperature of said site as a function of time, computing therefrom the total state of cure of said part of the article as a function of time and terminating the heat supply when a predetermined state of cure has been reached, said total state of cure of the part of the article being computed in terms of a number of cure units, one cure unit being that cure received at the point under consideration in the article when maintained at a specified reference temperature for one minute.

2. A method according to claim 1 in which the number of cure units is computed using the Arrhenius equation.

3. A method according to claim 1 in which the number of cure units is computed using the expression $tC^{(T_2-T_1)}/y$ which gives the state of cure at a temperature T_2 where t is the elapsed time of cure, T_1 is the predetermined reference temperature and C and Y are constants.

4. A method according to claim 3 in which the curable article is a natural or synthetic rubber article, $C = 2.0$ and $Y = 18$.

5. A method according to claim 1 in which the assessment of the relationship of the actual temperature of cure with the predetermined reference temperature of cure is not commenced until a predetermined minimum temperature of the point under consideration is attained.

6. A method according to claim 1 in which the total state of cure at the predetermined site is computed directly by monitoring the local temperature of the site as a function of time.

7. A method according to claim 1 in which the total state of cure is computed indirectly by monitoring the local temperature of said site as a function of time, the local temperature of the site and its deviation from a predetermined ideal temperature-time variation being determined at regular intervals or continuously, and an adequate correction being applied by suitable adjustment of the heat supply.

8. A method according to claim 1 in which the predetermined state of cure is less than the state of cure required in the finished article to compensate for the additional curing by the heat remaining in the article after the heat supply has been terminated.

9. A method according to claim 1 in which the temperature sensing probe is located within the article at a site which, after the heat supply has been terminated, has the lowest state of cure.

10. A method according to claim 1 in which the article is a rubber tire.

11. A method according to claim 10 in which the tire is a cross-ply tire and predetermined site is in the lower shoulder region of the tire.

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APPENDIX G

UNITED STATES PATENT OFFICE

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METHOD OF CURING A RUBBER OR PLASTIC TIRE

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Continuation-in-part of abandoned application Ser. No. 857,642, Sept. 10, 1969, which is a continuation of application Ser. No. 640,324, May 22, 1967. This application Sept. 11, 1969, Ser. No. 857,175

Claims priority, application Great Britan, Mar. 24, 1966,

12,969/66

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U.S. Cl.264—40 13 Claims

ABSTRACT OF THE DISCLOSURE

A method for determining the state of cure of a rubber or plastics article, such as a pneumatic tire, during its cure cycle by sensing the temperature of the article at its surfaces, calculating therefrom the temperature at a point in the article at which an

adequate state of cure is desired and thence determining the state of cure at such point. Also the process for curing a rubber or plastics article which includes using the above method to determine the state of cure at a point in the article and terminating the cure when a desired state of cure at that point has been reached, of which the following is a specification.

This application is a continuation-in-part of application Ser. No. 857,642, filed Sept. 10, 1969, now abandoned, which in turn is a continuation of application Serial No. 640,324 filed May 22, 1967, now abandoned.

This invention relates to the curing of rubber or plastics articles and is particularly concerned with the determination of the state of cure of rubber articles.

In the manufacture of rubber articles, where the article is made from or includes a vulcanizable rubber compound, it is necessary to cure the compound by heating it to effect vulcanization. An optimum state of cure is obtainable for any given rubber compound, the physical properties of the cured rubber being adversely affected by substantial over or under cure.

Over cure or under cure is sometimes obtained on account of variations, during a cure of a predetermined duration, in the temperature of the steam utilised for heating moulds within which rubber articles are cured. Variation in the temperature of the

mould can also take place due to variation in the ambient temperature, variation in the temperature of the heating media and the transfer of heat therefrom to an article to be cured, the degree of use to which the mould is put, i.e. the amount of heat extracted from the mould per unit time and the period during which the mould is left open between curing operations. It is, therefore, desirable to have a method of or an apparatus for, determining the state of cure of the article.

According to the invention there is provided a method of determining the state of cure of a part at least of a rubber or plastics article during the curing thereof comprising sensing at intervals of time the temperature of cure at at least two boundary surfaces of the article, calculating, from each set of said boundary surface temperatures, the corresponding temperature at a point at which an adequate state of cure is desired, said point being located between the boundary surfaces, assessing the relationship of the calculated cure temperature with a predetermined reference temperature of cure and accounting for the elapsed time of cure to determine the state of cure at said point in the article.

In one example of the above method the calculated cure temperature is compared with the predetermined reference temperature of cure to determine the variation between the two temperatures and wherein the temperatures of cure at the boundary surfaces of the article are sensed at uniform intervals of time, said boundary temperatures being sensed at the commence-

ment of each time interval and the corresponding temperature at the point at which said adequate state of cure is desired being forecast for the end of such time interval.

This is forecast using a calculation based on a knowledge of the dimensions of the article, the thermal properties of the article and the time-temperature conditions at surfaces where heat is applied to the article.

* * * * *

The method according to the invention thus renders it possible to calculate the state of cure at the point under consideration at any time in terms of aggregate number of cure units and to terminate the cure when the desired cure corresponding to a predetermined aggregate number of cure units has been obtained. The time of cure which will provide a specified number of cure units, will vary from one article to another sample of the same article, since as the cure temperature unavoidably varies so must the duration of cure to ensure that each article receives an adequate quota of cure units to ensure that the finished cooled article is not substantially over or under cured.

* * * * *

The apparatus for determining the state of cure of a part at least of a rubber or plastics article comprises at least two temperature sensors locatable one at each of at least two boundary surfaces of the article to be cured, calculating means for determining the temperature of the article at a point between the

boundary surfaces at which an adequate state of cure is desired, means for assessing the relationship of the calculated temperature with a predetermined reference temperature of cure and means for accounting for the elapsed time of cure to determine the state of cure at said point in the article.

Preferably the calculating means, the means for assessing the relationship of the calculated temperature with the reference temperature and the means for accounting for the elapsed time of cure comprises a computer device.

An alarm system may be provided which is operable if any or all of the factors contributing to a satisfactory cure of the tire deviate substantially from a predetermined range of values.

Also in accordance with the invention there is provided a cured rubber or plastics article e.g. a pneumatic tire, wherein the state of cure during the curing of such an article has been determined by the method or apparatus described above.

* * * * *

Having now described our invention what we claim is:

1. A method of curing a rubber or plastics tire by controlling the amount of cure at a point within said tire remote from direct measurement thereof comprising:

(a) initially heating said tire;

(b) thereafter at intervals of time measuring the temperature of at least two boundary surfaces at points which, together with the point within said tire, lie on a straight line parallel to the direction of heat flow through the tire;

(c) determining the temperature at said point within the tire from said boundary temperatures as a function of the thermal conductivity, density and specific heat of said tire along said straight line at the then existing temperature of said tire and continuing the heating of said tire as a function of the temperature at said point;

(d) determining the state of cure in cure units at said point within said tire from said temperature at said point,

(e) terminating the heating of said tire when the state of cure in cure units at said point within said tire reaches a predetermined level which is the number of cure units necessary to achieve the desired cure, one cure unit being the amount of cure inserted per unit time at a point in the tire when the temperature at that point is a selected reference temperature.

2. A method according to claim 1 in which the number of cure units at said point within said tire is defined by the expression

$$tC \quad \frac{(T_2 - T_1)}{Y}$$

where t is the elapsed time of cure, T_1 is the selected reference temperature and C and Y are constants.

3. A method according to claim 2 in which the article is a natural or synthetic rubber tire being vulcanized using sulphur and T_1=287° F., C=2.0 and Y=18.

4. A method according to claim 1 in which the number of cure units at said point within said tire is defined by the Arrhenius equation.

5. A method according to claim 1 in which the number of cure units at said point within said tire is defined by a polynomial equation.

6. A method according to claim 1 wherein determination of the state of cure in cure units is commenced after the temperature at said point reaches a predetermined temperature.

7. A method according to claim 6 wherein the minimum predetermined temperature is 210° F.

8. A method according to claim 1 in which the tire is a pneumatic tire and the curing is carried out in a mould.

9. A method according to claim 8 wherein the boundary surfaces comprise a tread surface of the tire at the shoulder region thereof and a surface adjacent said shoulder region of a cure bag or diaphragm located within the mould.

10. A method according to claim 1 in which the tire is cured in a mould further comprising:

(e) cooling said tire within said mould

(f) thereafter measuring the temperature of at least two said boundary surfaces of said tire at intervals of time

(g) continuing the cooling of said tire as a function of the temperature at a point located between the boundary surfaces of the tire, the temperature at said point being determined from the temperatures of the boundary surfaces

(h) terminating the cooling of said tire when the temperature at said point reaches a predetermined level

(i) opening said mould and removing said tire.

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